the STORY of LIFE

REAYAT KHAN MOONIS RAZA

SHAKTI AHMED

General Education Reading Material Series
No. 10

THE STORY OF LIFE

ALIGARH MUSLIM UNIVERSITY
GENERAL EDUCATION READING MATERIAL SERIES

GENERAL

1. What is General Education?
2. Man in the New World

ARTS AND PHILOSOPHY

3. An Introduction to European Painting
4. An Introduction to Indian Painting
5. An Introduction to Indian Architecture
6. An Introduction to Hindustani Music
7. Man, Reality and Values
8. Readings in Philosophy

NATURAL SCIENCES

9. The Earth We Live On
10. The Story of Life
11. Universe and the Atom
12. Science and Society
13. Significant Writings on Life and Man
14. Science: Its Method and Outlook
15. The Changing Concept of the Universe

SOCIAL SCIENCES

16. Indian Culture
17. Evolution of Society
18. Modern Industrial Society
19. Modern Indian Society
20. Messages of Freedom
21. Readings in Democracy
22. Significant Writings on Social Organization
23. Gleanings from Indian Thought

LITERATURE

24. Selections from Hindi Literature, 2 vols.
25. Selections from Urdu Literature, 2 vols.
26. Selections from World Literature, 4 vols.
27. What is Literature?

DIRECTORATE OF
GENERAL EDUCATION READING MATERIAL PROJECT
ALIGARH MUSLIM UNIVERSITY

THE STORY OF LIFE

REAYAT KHAN MOONIS RAZA
SHAKTI AHMED

ASIA PUBLISHING HOUSE
BOMBAY . CALCUTTA . NEW DELHI . MADRAS
LUCKNOW . LONDON . NEW YORK

© ALIGARH MUSLIM UNIVERSITY 1965

370
K S

राज्य संग्रहालय पुस्तकालय, लखनऊ
क्रम संख्या 3767
प्राप्ति तिथि 14/3/69
State Museum, Library, Lko.

3767

PRINTED IN INDIA

BY B. G. DHAWALE AT KARNATAK PRINTING
PRESS, BOMBAY AND PUBLISHED BY P. S.
JAYASINGHE, ASIA PUBLISHING HOUSE, BOMBAY

Foreword

THE vital role that general education can play in our universities is now being gradually recognized in academic circles. The Radhakrishnan Commission Report published in 1950, first emphasized the need for general education and made certain recommendations for its provision. The Ministry of Education organized conferences and seminars and drew the attention of universities towards its significance. A number of teachers and scholars drawn from various universities visited the United States and the United Kingdom to study the working of general education at various centres and to get first hand knowledge about the progress of various programmes of study. The University Grants Commission has now engaged the services of an expert to advise Indian universities on the implementation of general education programmes and fifteen universities have already made these programmes a part and parcel of their regular course of studies.

Aligarh Muslim University was among the first to adopt a full and integrated programme of general education courses. Experience showed clearly the need for reading material to be especially prepared for the purpose of this new type of teaching which differs from the traditional one in method as well as in content. When approached, the University Grants Commission entrusted Aligarh Muslim University with the task of preparing reading material suitable for general education courses at Indian universities.

The series here presented, like general education itself, may not find agreement among all concerned. It is not meant to serve as a text which would be completely digested, let alone memorized or crammed. On the contrary it is intended to arouse curiosity, stimulate thinking and broaden the outlook of our students. The selections and samples are expected to enable students to use their intelligence and widen their understanding and appreciation. They may lead to a sense of values urgently needed today.

Another important and accepted aspect of general education is its complementary character. In our country, there is a great and urgent need for more people who are properly trained and educated to earn a living through performing competently the many functions on which our society depends. It is equally important, however, that colleges and universities also impart an education which enables students to live a fuller and more rewarding life. To quote the Report of the University Education Commission (pages 118-119): "The interests and opportunities and demands of life are not limited to any few subjects one may select to study. They cover the entire range of nature and of society. That is the liberal education which best enables one to live a full life, usually including an experience of mastery in some specialized field. . . ." To a student "a general education course should open windows in many directions, so that most of the varied experiences of his life and most elements of his environment, shall have meaning and interest to him."

The task, then, in preparing reading material for general education purposes was clear as well as complex. On the one hand, the mounting walls between the ever-increasing number of compartments of specialized knowledge had to be disregarded so that fragments could be re-assembled into that unity of knowledge which exists in human experience. On the other hand, it was necessary to present only so much of content as students in all traditional branches of knowledge could be expected to manage and to understand as an integrated whole. For, as Whitehead rightly remarked, "a student should not be taught more than he can think about."

Furthermore there is agreement that integration cannot be achieved by providing students with readymade opinions concerning questions that arise in the course of general education. On the contrary, if they are to be encouraged to think for themselves and to seek their own answers, they have to be confronted with errors of the past or doubts of the present, with divergent judgements or open alternatives, as well as with the beauty of scientific proof or the force of moral conviction.

The complete scheme of this series will be found on page ii where a systematic list of the publications is shown. While it adheres to the traditional division into Natural Sciences, Social Sciences and Humanities, many of the expository volumes straddle more than one field, and most of the source material touches upon problems not easily assigned to any one area only.

No student is likely to read and absorb all volumes; but every student will find instruction and inspiration in several of the volumes if he uses them properly under the guidance of his teachers. Large though the collection is, it cannot possibly aspire at complete comprehensiveness. Since "selection is the essence of teaching" (Whitehead) it had equally to be the principle of planning of this series. And since choice implies omission, many important disciplines had to be somewhat neglected, and others to be left out entirely. Unavoidably, what is here regarded as the result of careful consideration, may elsewhere appear as arbitrary.

The readers of these volumes, teachers and students alike, are the ones whom this publication wants to serve. From them, too, the authors, compilers, editors and advisers of this project hope to hear. It represents a co-operative effort in preparation and publication. Its success depends on further co-operation between "producers and consumers." Comments and criticisms are invited, to be addressed to: Co-ordinator, General Education, Aligarh Muslim University, Aligarh. Since it is planned to translate the series into Hindi and Urdu, changes which may seem desirable, can easily be introduced when this is done.

In the end, the University acknowledges with gratitude the services rendered by the various contributors, reviewers, and the members of the Advisory Committee and all those due to whose keen interest and ready co-operation, the Directorate has been able to complete the Project. We are particularly grateful to the University Grants Commission who entrusted us with the task and assisted us liberally in this venture.

B. H. ZAIDI
Vice-Chancellor

Aligarh Muslim University
1962

Preface

THE story of life is a fascinating one. Modern educationists feel that the fundamentals of this story should be known to all educated persons. The present book has been written as an attempt to fulfil this purpose. No previous knowledge of the subject is required to understand the book. Special effort has been made to present the matter in a simple, interesting and easily understood manner. It has not been possible to avoid technical terms completely but they have been kept to a minimum.

The users of the book will most probably feel that they have suggestions to offer for improving it. Such suggestions and criticism are earnestly invited and will be gratefully appreciated.

Some readers would like to know more about living beings than what they are told here. The books marked with an asterisk in the list given in the following paragraph are of a general character and are, therefore, recommended for further reading.

The subject matter of this publication is spread over the pages of scores of books. It has really become the common property of mankind and it is not practicable to acknowledge original sources. The diagrams for Parts I and II have been copied from the following books:

*Baker, A. O. and L. H. Mills, *Dynamic Biology Today*, Rand McNally & Co., New York; *Beadnell, C. M., *A Picture Book of Evolution*, Watts & Co., London; Dobzhansky, T., *Evolution, Genetics and Man*, John Wiley & Sons, New York; *Hardin, G., *Biology—Its Human Implications*, W. H. Freeman & Co. San Francisco, California; Lock, R. H., *Variations, Heredity & Evolution*, John Murray, London; *Mavor, J. W., *General Biology*, The Macmillan Co., New York; Sharp, L. W., *Fundamentals of Cytology*, McGraw Hill Book Co., New York; Sinnott, E. W., L. C. Dunn and T. Dobzhansky, *Principles of*

Genetics, McGraw Hill Book Co., New York; Stirton, R. A., *Time, Life and Man—The Fossil Record*, John Wiley & Sons, New York; and *Wheeler, H., *The Miracle of Life*, The Home Library Club.

Grateful acknowledgment is made to the authors and publishers of all these works which have also been mentioned under each diagram separately.

Contents

PART I

THE SCIENCE OF LIFE

By Reayat Khan

1. INTRODUCTION 3
The Science of Life; Plants and animals in relation to man.
2. THE RIDDLE OF LIFE 6
What is life?; The Scientists' way of looking at life.
3. KINDS OF LIVING THINGS 11
Variety in the world of life; Variety in the plant kingdom; Variety in the animal kingdom; Classification and nomenclature.
4. THE BODY OF LIVING THINGS 17
What is an organism?; Organization in a complex animal body; Organization in a complex plant body; Organization in a simple body.
5. THE CELL 28
Structure of cells; The living matter; The cell as the unit of organization; The cell as the functioning unit.
6. REPRODUCTION 34
Sexual reproduction; Variety in the methods of reproduction; Cell division and reproduction.
7. HEREDITY 40
The meaning of heredity; Biological inheritance and chromosomes.
8. THE MECHANISM OF HEREDITY 45
The principle of segregation; Principles of independent assortment and linkage; Importance of genetics.

PART II

THE EVOLUTION OF LIVING BEINGS

By Reayat Khan

9. THE MEANING OF ORGANIC EVOLUTION 55
The historical approach; History of the living

world; The theory of organic evolution.
10. IS IT POSSIBLE? 59
11. EVIDENCES OF ORGANIC EVOLUTION—PART I 63
Sources of evidence; Fossil evidence of organic evolution; Fossil evidence—the historical sequence; Fossil evidence—a closer study; Fossil evidence—the connecting links.
12. EVIDENCES OF ORGANIC EVOLUTION—PART II 74
Classification as evidence of evolution; Comparative anatomy; Vestigial organs; Comparative embryology; Selection and breeding; Other sources of evidence.
13. EVOLUTION OF THE THEORY OF EVOLUTION 79
The early period; Lamarck's theory of evolution; Darwin's theory of natural selection; Weismann and the inheritance of acquired characters; De Vries and the mutation theory; Mechanism of evolution—modern views; A review.
14. THE ORIGIN OF LIFE 89
15. THE MORAL OF EVOLUTION 93

PART III

THE EVOLUTION OF MAN

By Moonis Raza

16. THE ANCESTRY OF MAN 103
Life is a unity; Our family tree; The era of mammals; The paleocene; The eocene; The oligocene; The miocene; The pliocene.
17. THE CURTAIN RISES 109
The stage is set; How we came to know of the ice age; The advance and retreat of the ice; The woolly mammoths; Man enters the scene.
18. DOWN TO EARTH 113
Standing on one's feet; Forepaws become hands; The transformation of the teeth; The face changes; Man become a talking animal; The language of gestures; The language of sound; The human mind.
19. THE MISSING LINKS 120
A fairy tale; A scientific fact; The anthropoid of the South; What they looked like; Cranial capacity; The position in man's family tree; The search in South Asia; The ape man who walked erect; How they were built; How is the Java man related

to us?; Bones on the foot of the Chick Hillock; The body of the Peking man; Sinanthropus and our genealogy; The search in Europe; Neanderthal man comes to the aid of Charles Darwin; The body of the Neanderthal man; The fall of the curtain; The curtain rises again; The place of man in the map of life.

20. FROM THE AGE OF MUMMIES TO THE TIMES OF HARVEY 134

The age of mummies; Hippocrates—the voice of science; Workers and thinkers; The theory of numbers; The theory of "four humours"; The museum at Alexandria; The contribution of Galen; The dark ages; Astrology and incantations; The Arab renaissance; Light dawn in Europe; The invisible pores; The contribution of Harvey.

PART IV

WORKING OF THE HUMAN BODY

By SHAKTI AHMED

21. FOOD OF THE HUMAN BODY 145

22. HOW FOOD IS USED IN THE BODY 150

Digestion; Assimilation; Release of energy; Energy requirement; Oxygen for cumbustion—respiration; Transport of oxygen and fuel, removal of waste products—blood circulation; Cells as chemical factories—metabolism; Removal of waste products from the body—excretion; Co-ordination of functions; Nervous system; Control of body temperature; Man, the thinking animal; Reproduction.

23. HEALTH AND DISEASE 163

Diseases due to hormonal unbalance; Diseases due to malnutrition; Diseases due to foreign bodies; The defence system of the human body; Immunity; The health of the people.

ILLUSTRATIONS 169

INDEX 207

Part I

THE SCIENCE OF LIFE

CHAPTER ONE

Introduction

The Science of Life

What is life ? How did it first come into existence ? How have living beings developed from their beginnings to their present stage ? How do they grow, produce their young, and pass on their bodily and mental qualities and defects to them. What is the importance of plants and animals in man's everyday life ? Can man create living beings, including a human being ? The science that attempts to find answers to these and similar questions is called the Science of Life or Biology.

Man is a living being. It is, therefore, natural that he should feel interested in knowing about life and living beings, i.e. about plants and animals. It is not merely to satisfy his natural curiosity that he studies life and living things. Nor does he study these things just as an ideal pursuit or a hobby. The students of the science of life try to understand how the various organs in the bodies of plants and animals are made, how each of them works and how they work together. They study how plants and animals obtain power to perform various actions. They try to find out what causes different actions. They try to know how plants and animals produce other plants and animals like themselves. They see that plants and animals living at a particular time are not only like their parents and grandparents in many ways but also that they differ from them. They try to find out the reasons for these resemblances and differences. With knowledge thus obtained, biologists advise us as to what and how we should eat, what we should do so that children may grow properly, how we can keep fit and be free from illness. All this knowledge helps us in making our society healthy and strong.

Everything has a history. Living beings have their own history. Plants and animals were different in the past from what they are today. They had a beginning, long long ago. And then they developed from their original form to newer and newer forms through many ages, covering many millions of years. They spread all over the earth and acquired many new and different forms, structures and habits. The first simple living things lived in water. They produced new kinds of living things. Some of these became plants or animals while others had the properties of both. Later came more complex forms. Plants that produced no seeds and flowers developed into plants that bore flowers and produced seeds. Animals that at first lived in water developed into those that could live on land. On land, some of the reptiles (animals like snakes, crocodiles, lizards etc.) developed into birds, while others developed into mammals, i.e. those animals that feed their young with milk from the breast, like dogs, cows, apes or monkeys and Man.

The historical development of living beings is known as evolution. They story of evolution is very interesting. It has great importance for man in many ways. It has influenced many branches of human knowledge. It has helped us to understand man in relation to other living beings and in relation to the non-living world. It has changed our attitude towards many social problems. It has enabled us to see ourselves in proper perspective.

Plants and Animals in Relation to Man

All human beings, from those belonging to the earliest times to the civilized man of today, need plants and animals for their very existence. In order to live, we must have food. All our food comes from plants and animals. Our foodgrains like wheat, rice, barley, and maize, pulses and beans, sugar, vegetables and fruits, spices and tobacco, different drinks like tea, coffee, cocoa and wines, all come from plants. We get eggs, milk and meat from different animals. Milk is made into curd, butter, ghee and cheese. Some trees also yield 'milk'; e.g. the famous "cow-tree" of Venezuela.

Besides food, without which we could not live, plants and animals also provide us with many other necessary things. From plants we get wood for building our houses and furniture, for cooking our food and warming ourselves. Early man covered his body with the bark and leaves of plants and skins of animals. Today we use for our clothes cotton, silk and wool. We go about from place to place in carriages, trains, boats, ships and aeroplanes and these could not be built without wood.

As already stated Biology has been of very great help to us in keeping fit and healthy. We now understand better the nature and importance of what is called a balanced diet. The discovery of vitamins and their importance in nourishment helps us to avoid some serious diseases such as rickets and beriberi. We realise the part played by certain substances produced in the human body called hormones. Some very tiny living beings, so tiny that they can be seen only with the help of a microscope, are germs. These germs cause cholera, small-pox, malaria, tuberculosis etc. The study of these living beings has enabled man to control the spread of these diseases to a certain extent. Vaccination saves us from small-pox and some other diseases. Many of our medicines are made from leaves, roots, bark, or flowers of plants.

The study of the structure of living beings has been of great help in operations performed on patients by surgeons. Wounds do not get worse now as the doctors know how to kill germs which make it difficult for wounds to heal quickly. Some defects and diseases are passed on from parents to children. A study of how plants and animals receive certain qualities or defects from their ancestors and how these can be changed by man has led to an understanding of some of these diseases.

The great practical value of the study of life and living beings, viz. plants and animals, is clear even from this very brief account. Its theoretical importance is no less great as it attempts to find answers to some very important questions.

CHAPTER TWO

The Riddle of Life

What is Life?

Life is a riddle. We know a great deal about it, but we do not know enough about its real nature and its origin. The preparation of living matter from non-living in the laboratory is still merely a dream. Theoretically it is not an impossibility, but no one can say with certainty when this will actually be achieved.

Living matter does not contain any element which is not found in non-living matter. Energy, too, which is the basis of all life activities is not different from the energy existing outside living bodies. Yet the simplest living organism is more complex than the most complex machine ever created by man. The latter can be taken to pieces and the parts fitted together again. This is not possible in the case of even the simplest living body.

The substance from which the bodies of all living beings are built is called living matter or protoplasm. Burning needs combustible matter, oxygen and a suitable temperature. Colour needs a material body placed under proper conditions of lighting. Movement needs something in motion. It is not possible to conceive of burning without the matter that burns, of colour without the body that exhibits colour, of movement without the thing in motion. In the same way, it is not possible to conceive of the existence of life without the body of living organisms.

Living matter has assumed many different forms during the course of its development. In size living beings vary greatly. At one extreme are giants like eucalyptus and redwood trees and whales or elephants. At the other extreme are living beings which are too small to be seen without a microscope. Some of these are only 1/1000th of a millimetre in size. In these, protoplasm is in the form of just a tiny speck or droplet. The body of a larger-sized living being, such as a pea plant, an ant, or a human being consists of a large number of such droplets of protoplasm. When a drop of man's blood is examined under the microscope, it shows a very large number of such tiny specks of protoplasm floating in a fluid. A drop of the size of a fullstop on this page may contain several lakhs of these specks, or tiny bits of protoplasm. We can imagine the total number of such specks in a man's body! These tiny specks of protoplasm have been given the name of "cells". They have been compared to the bricks of a building. Cells move freely in the blood, but in other parts of the body they are joined together firmly in tissues forming various organs.

Cells differ a great deal in size and shape but the important features are the same in all cells. A plant or animal body may consist of almost innumerable cells or only a few cells or just one single cell of protoplasm.

A very obvious property of many living beings is their power of movement. This movement takes place naturally in all living matter, and does not depend upon external agencies such as the wind in the case of dust particles or gravity in the case of water in a stream. In one kind of movement the entire body is transferred from one place to another. Such movements are made by animals that move from one place to another and we all know it. But there are some animals that are fixed like plants. There are many plants that move about freely from place to place like animals. Such plants are very small and live in water. The person who is not an expert is not familiar with them. Even those plants that are fixed to the ground show slow movement of their parts while they are growing. The roots and shoots grow and extend in various directions in the soil and in the air. Roots have the tendency to move away from light and to move down into the earth. Shoots have the ability to move away from darkness and to grow towards light or the sun. Apart from these, there is the natural movement of protoplasm inside the cells. As in the case of cellular structure, there is no essential difference between plants and animals in respect of their tendency towards spontaneous or natural movement.

The ability of roots to grow in darkness away from light or of shoots to grow towards light are examples of responses to stimuli, i.e. effects of external causes. In this case light is the stimulus, the external cause. The resulting mode of growth, either away from or towards light, is the response, the effect. The capacity to respond to a stimulus is called irritability. Movements occur frequent-

CC-0. Agamnigam Digital Preservation Foundation, Chandigarh

ly in response to stimuli and are, therefore, expressions of irritability. The stimulus, however, does not provide the energy for the movement or the response. It only acts as a signal or as the trigger of a gun. Shivering caused by cold or fright, perspiration caused by heat, the secretion of saliva ("ral") caused by the presence of food in the mouth or even by the mere sight or smell of food, the well-known responses of anger, fear, love and kindness caused by relevant situations, movements of the leaflets of mimosa ("chhui mui" or "lajjavati") in response to mere touch are further examples of irritability. Irritability is one of the fundamental properties of protoplasm both in plants and animals.

Living organisms require food, water, air etc. for maintaining their life and for performing various activities. They have the ability to change the shape and nature of their food until it becomes the living matter of their bodies. All the activities of living beings depend upon energy. This energy is produced as a result of breathing. When a living being breathes, the oxygen which is breathed in combines with complex substances built up by it from the food it takes in. These substances then break down into simple substances, producing energy during the process. Many observers have compared living organisms to machines from which they get energy, and their food, to fuel. Transformation or complete change of food into the substance of the body and then its breakdown, with consequent production of energy is called metabolism. Metabolism is another feature characteristic of all living beings, regardless of whether they are plants or animals.

Animal or plant growth is the result of the change of the non-living matter of food into the living matter of their bodies. A tiny seed grows into a gigantic tree and a small baby grows into a fully developed man. Crystals, stalactites and stalagmites and mountains also increase in size. But they grow only by the addition of matter. Growth is a common characteristic of all living organisms.

Scientists consider the power of reproduction as the most important distinguishing property of living beings. Reproduction is the production of one or more individuals from those already in existence. This ability to increase their own number is a very remarkable property of living beings. While old living beings die, new ones are born. Individuals die but life continues. Reproduction, including sexual reproduction, is common to both plants and animals.

To summarise, all living organisms—plants and animals—are characterised by the presence of protoplasmic cells, the power of spontaneous movement, irritability, metabolism, growth and reproduction.

The Scientists' Way of Looking at Life

The aim of science is the search for truth. Scientists carry on this search in a distinctive manner. Their method of approach is called the scientific method. It has inspired such confidence in people that even those who do not look upon science with favour claim to be scientific in their method and outlook.

Science is not based on common talk, superstition, prejudices or unreasonable customs and beliefs passed on from generation to generation, doctrines and principles taught by some authority, e.g. the Church, or blind faith. Scientists are guided by facts. When a scientist sees something new for the first time he observes it critically. He then observes it repeatedly under different conditions, to be sure that what he is observing does exist in reality and does not merely appear to exist. He compares his observations with those of other scientists. He applies his mind to a critical examination of what he has observed. Then he draws a conclusion for the time being. He performs experiments to test the correctness of his provisional conclusion. If the results of many experiments agree with his conclusion, he adopts it as "final", again only for the time being. He keeps an open mind, does not entertain an emotional or sentimental attachment to his own discoveries and ideas. He does not say that his observations and conclusions are the last word on the subject. Neither does he ordinarily keep his technique and data secret. On the other hand, he publishes them in recognized scientific journals. And, he is prepared to revise or reject his conclusions if someone else proves that there was some fault in his observations, experimentation or reasoning. Intelligent guessing and logic have their place in science but they are based upon observation and reason.

A scientist does not accept ideas simply because they have been accepted by human beings for a long time or because they come from people who have been or are respected for some reason or other. When he comes face to face with such ideas, he employs his scientific method to test their correctness. When a scientist is unable to explain some phenomenon, he admits his inability and ignorance. He does not jump to the conclusion that his inability to explain something with the help of scientific reasoning proves the existence of supernatural forces. He expresses the hope that the discovery of more facts or a new explanation of known facts may explain in future what he cannot explain at present.

The scientist attempts to apply his special method to the study of life in the same way as he applies it to other things in nature. Life processes are to him natural phenomena. Like everything else, they are the result of the operation of natural forces. He does not classify some phenomena as natural and others as supernatural. He is not willing to describe anything as supernatural simply because it is beyond man's power to achieve or to comprehend. He does not believe in miracles in the sense that things might happen as if by magic. He admits the possibility of the cripple being made to walk, of the blind being enabled to see, of the deaf being made able to hear, or, under certain conditions, of even the dead being brought back to life. But he does not think this can be done by, say, someone merely uttering a certain word or words or just by waving a magic wand. The only miracles to him are amazing scientific inventions like the telephone, the radio, the aeroplane, the sputnik, modern surgery or antibiotics.

The scientist has the same rational outlook towards the problems of health and disease. He does not believe that epidemics like plague and cholera are the expressions of God's wrath and punishment for the sins of man. To avoid pox he will not recommend offerings at the temple of a particular goddess or at the graves of holy men. He does not believe in talismans, witchcraft or quackery. He follows the established principles of hygiene, sanitation and scientific medicine.

CHAPTER THREE

Kinds of Living Things

Variety in the World of Life

Have you ever tried to guess how many different kinds of living beings there are in this world ? If you look around yourself carefully in your village or in the parks and gardens in cities, you see many kinds of plants and animals. When you visit a botanical garden or a zoo, or when you go on a journey to new places; to a hill or to the sea, you see many more new and unfamiliar plants and animals. You begin to feel that there are thousands of plants and animals, each of a different kind. Biologists, after making a careful study of all living beings on the earth and in the sea have discovered, named and classified more than a million different kinds of plants and animals. They feel that many kinds are yet to be discovered. Remember, this is the number of "kinds" or, in scientific language, "species". This is not the number of individuals. Roughly speaking, all mango trees are one kind or species of plants, and all dogs or pigeons are one kind or species of animals. It is well-known that this one kind of plant, the mango, itself, shows variety. "Langra", "Dasehri", "Fajri" and "Maldah" are the names of only a few out of many varieties. Dogs or pigeons, similarly, are of many different varieties (FIG. 1). One species or "kind" of plants or animals may comprise scores or hundreds of varieties. And yet, this is not the end. There can be and there actually is variety within varieties. How has this almost endless variety come about? The answer to this question will be clear only after a study of the historical development of living beings and of the factors that have controlled this development or evolution.

Most of the organisms in the world of life can be classified either as plants or as animals. Biologists often feel happy to refer to them as the plant kingdom and the animal kingdom. There are, however, some living beings that possess the distinctive features of both. These are described in the text books of botany other. When he comes face to face with such ideas, he employs his scientific method to test their correctness. When a scientist is unable to explain some phenomenon, he admits his inability and ignorance. He does not jump to the conclusion that his inability to explain something with the help of scientific reasoning proves the existence of supernatural forces. He expresses the hope that the discovery of more facts or a new explanation of known facts may explain in future what he cannot explain at present.

The scientist attempts to apply his special method to the study of life in the same way as he applies it to other things in nature. Life processes are to him natural phenomena. Like everything else, they are the result of the operation of natural forces. He does not classify some phenomena as natural and others as supernatural. He is not willing to describe anything as supernatural simply because it is beyond man's power to achieve or to comprehend. He does not believe in miracles in the sense that things might happen as if by magic. He admits the possibility of the cripple being made to walk, of the blind being enabled to see, of the deaf being made able to hear, or, under certain conditions, of even the dead being brought back to life. But he does not think this can be done by, say, someone merely uttering a certain word or words or just by waving a magic wand. The only miracles to him are amazing scientific inventions like the telephone, the radio, the aeroplane, the sputnik, modern surgery or antibiotics.

The scientist has the same rational outlook towards the problems of health and disease. He does not believe that epidemics like plague and cholera are the expressions of God's wrath and punishment for the sins of man. To avoid pox he will not recommend offerings at the temple of a particular goddess or at the graves of holy men. He does not believe in talismans, witchcraft or quackery. He follows the established principles of hygiene, sanitation and scientific medicine.

CHAPTER THREE

Kinds of Living Things

Variety in the World of Life

Have you ever tried to guess how many different kinds of living beings there are in this world ? If you look around yourself carefully in your village or in the parks and gardens in cities, you see many kinds of plants and animals. When you visit a botanical garden or a zoo, or when you go on a journey to new places; to a hill or to the sea, you see many more new and unfamiliar plants and animals. You begin to feel that there are thousands of plants and animals, each of a different kind. Biologists, after making a careful study of all living beings on the earth and in the sea have discovered, named and classified more than a million different kinds of plants and animals. They feel that many kinds are yet to be discovered. Remember, this is the number of "kinds" or, in scientific language, "species". This is not the number of individuals. Roughly speaking, all mango trees are one kind or species of plants, and all dogs or pigeons are one kind or species of animals. It is well-known that this one kind of plant, the mango, itself, shows variety. "Langra", "Dasehri", "Fajri" and "Maldah" are the names of only a few out of many varieties. Dogs or pigeons, similarly, are of many different varieties (FIG. 1). One species or "kind" of plants or animals may comprise scores or hundreds of varieties. And yet, this is not the end. There can be and there actually is variety within varieties. How has this almost endless variety come about? The answer to this question will be clear only after a study of the historical development of living beings and of the factors that have controlled this development or evolution.

Most of the organisms in the world of life can be classified either as plants or as animals. Biologists often feel happy to refer to them as the plant kingdom and the animal kingdom. There are, however, some living beings that possess the distinctive features of both. These are described in the text books of botany (science of plants) as well as zoology (science of animals). This emphasizes the fact that there is no sharp line of demarcation, or a fixed borderline, between the two kingdoms. Life is essentially one.

There is no absolute distinction between plants and animals. But, for practical purposes, certain general distinctions have been recognized. Among these, the presence of the green colouring matter, the chlorophyll, in most plants and its absence in animals is the most important. Animals obtain their food either directly from plants or indirectly by eating other animals that get their food from plants. Plants, on the other hand, are independent of animals in the matter of their food. This independence is due to the presence of chlorophyll. Thus, while plants can exist and flourish in the absence of animals, animals cannot live without plants.

Variety in the Plant Kingdom

There are about 200,000 known species of plants on our earth. The group of algae (pond scums, sea weeds etc.), the fungi (mushrooms, moulds) and the bacteria is supposed to show a closer approach to the earliest living beings than any other plant group. The bacterial individual consists of just a single cell. Algae may be one-celled, a few-celled or many-celled. Some of them, occurring in the sea, attain enormous sizes. Bacteria and fungi in general live a parasitic life upon other plants or animals. This mode of life is associated with lack of chlorophyll.

Mosses are a group of small plants seen in the rainy season, growing in moist, shady places. They show an advance over algae in attempting to live on land. Liverworts are closely allied to mosses. As land plants, the group of ferns and some other plants like lycopods, horsetails etc. show a higher degree of evolution. They also flourish best in cool, damp and shady places. Many of them look very pretty and are often grown in green-houses as ornamental plants. Although more highly evolved than algae, fungi, bacteria or mosses, they are still without flowers, fruits and seeds. Pines and cycads can lead a hardier life. Pines are tall trees and form extensive forests but they too do not bear fruit or fully developed flowers. They have seeds but these are not enclosed in a fruit. They are, therefore, called gymnosperms (gymnos—naked and sperma—seed).

Plants that bear flowers and fruit, with seeds enclosed within them, are the most recent in the history of the plant kingdom. They are called angiosperms (angeion—a case, i.e. seeds enclosed in a case). The pea, the mango, the wheat and the barley plants bear flowers, fruit, and seeds. Flowering plants show the greatest variety. The number of kinds or species of flowering plants amounts to about 100,000. In size they vary from about a millimetre to a few hundred feet in height. They grow almost everywhere, where life is possible. Some of them can capture, kill and digest small insects. They are the major source not only of our food but of most of our other requirements (FIG. 2).

Variety in the Animal Kingdom

More than 800,000 species of animals are already known to biologists. As in the case of plants, the group of animals consisting of a single cell or only a few cells is believed to approach the earliest living beings most closely. The amoeba is a well-known one-celled animal. It is well-known not only because in biology text books it is described as the typical one-celled animal but also because of the amoebic dysentery which it causes. The malarial parasite is another one-celled animal. It lives alternately inside the bodies of the mosquito and man. That is why mosquitoes must be destroyed in order to control malaria.

Among the more advanced animals are the sponges, the jelly-fishes, the flat worms and the round worms. Most of these animals grow attached to rocks or to other animals or to plants. Star-fishes are remarkable for their radial symmetry and star-like appearance. Snails, slugs, the octopus, the devilfish and the oyster have soft bodies covered with hard, calcareous shells of a great variety. Earthworms and leeches belong to the category of worms whose bodies are divided into a series of ringlike segments.

The largest group of animals, known as the arthropods, includes water-fleas, crabs, crayfish, centipedes, millipedes, insects and spiders. Though small in size, the insects are such a dominating group of animals that they present a challenge to man. Fish-moths, grasshoppers, termites, butterflies, moths, locusts, mosquitoes, flies, dragonflies, beetles, bugs, bees, wasps and ants are examples.

Some of them are the cause of serious human problems. Flies and mosquitoes spread disease. Locusts destroy crops. Some insects are useful as the honey bee which produces honey. Many insects visit flowers in search of food in the form of nectar and pollen. While gathering their food, they aid the plants in the process of their reproduction. This is an example of the interdependence of plants and animals. Many plants will not produce fruit and seed if insects are prevented from visiting them. Insects have a very highly evolved social life exhibiting division of labour, organization and discipline. Many biologists are of the opinion that man can learn a good deal from insects about the socialistic pattern of society.

All the animals mentioned so far are without a vertebral column or backbone. They are therefore called invertebrates. Animals with a backbone, called vertebrates, are much more highly evolved and recent than the invertebrates. Among the vertebrates are various kinds of fishes, amphibians like frogs and salamanders, reptiles such as lizards, snakes, crocodiles and alligators, birds of many kinds and mammals. Mammals are animals with mammae or breast glands which secrete milk for nourishing their babies. They also have hair. Mammals are the most recent and the most advanced members of the vertebrate group. They include, among others, duckbill, kangaroo, bat, dog, cat, lion, seal, rabbit, camel, ox, horse, monkey, ape and man. Monkeys and apes are nearer to man than any other animal. Man is the most recent and the most highly evolved of all animals. (FIG. 3).

Classification and Nomenclature

Whenever one has to deal with a large number of objects, one finds it necessary to arrange them according to some system. Without some sort of arrangement or grouping, there is confusion. If you have only a hundred books, you may not bother about arranging them. Even without any arrangement, you may find any particular book you want from the lot, without much difficulty. But if you have a million books without any grouping or classification, and you want to take out a particular book, you will very soon realize the indispensability of classification. Classification brings order and system where otherwise there would only be chaos and confusion.

When you are dealing with a very few things or persons, you may not label or name each one of them. But, again, suppose you are to deal with a million volumes of books without titles and authors' names, you will find that your work becomes impossible. It is imperative that each book or thing must have a name. Even if you have to deal with only a few things, you will find names indispensable. You cannot communicate with anyone else about a thing unless it has got a name for reference. Many plants and animals have common names like the banyan, the mango, the dog and Man. But scientists have to deal with a million species most of which have no names in the ordinary language. Scientists, therefore, have to name the organisms they discover. Each species is given a scientific name consisting of two words. The banyan tree is *Ficus bengalensis*, the mango tree is *Mangifera indica*, the dog is *Canis familiaris* and man is called *Homo sapiens*. The first word is a group name and is called a generic (adjective from 'genus') name. It is common to all those species which are very much alike and closely related to one another. For example, while the banyan tree is *Ficus bengalensis*, the closely related "peepal" tree is called *Ficus religiosa*. Another tree with noteworthy resemblances is "goolar" and has been named *Ficus glomerata*. The well-known fig is *Ficus carica*. As a matter of fact, the so-called fruit in all these four plants is very much fig-like and the word *Ficus* is simply the latin form of the word fig. To the generic name is added a word denoting something about the particular species. *Ficus bengalensis* means the fig of Bengal, *Ficus religiosa* is the fig with a religious significance, and so on. Scientific names are printed in italics or underlined in typescript or manuscript.

While the number of species of plants and animals runs into hundreds of thousands, a comparative study reveals that many species can be put together into groups. The bodies of those forming a particular group are built according to a plan which is common to all species of the group. Plants of wheat, barley, paddy, oats, rye, maize and sugar-cane have a common plan of structure which is also found in many wild grasses. All these are therefore put together into one group called the grass family. On the other hand, peas, grams, lentils and other pulses, the beans, the groundnut and many other plants all have common characteristics. These are considerably different from those found in plants belonging to the grass family. These, therefore, constitute another group, the pea family. You will easily note again that the sunflower, the dahlia and the marigold belong to another type and form a third family. Flowering plants comprising about 100,000 species are grouped into a few hundred such families.

In the vertebrate group of animals, the backbone is an important feature of the fundamental plan of structure. This large group can be split up into smaller ones on the basis of subsidiary plans within the major vertebrate plan. Thus, one can see groups within a group. All species of fish are water animals. They breathe with gills and have no lungs. They have no limbs but have fins. They constitute one group within the vertebrates. The pigeon, parrot, peacock, kite, eagle, ostrich and kiwi, though they appear to be so different from one another, possess certain common characteristics. They, therefore, form another group within the vertebrates. The horse, cow, dog, monkey, ape and Man etc. belong to the group of mammals.

The resemblances and differences, or the presence and absence of certain common plans of structure, are the basis of biological classification. Individuals that are very similar are grouped into a species. Similar species are grouped into a genus and closely related genera are put into a family. Families with noteworthy similarities form orders, orders form classes and the classes form phyla. Finally, the various phyla of plants constitute the plant kingdom and those of animals the animal kingdom.

What is the significance of a certain common plan of structure running through a number of species which also possess, at the same time, their own specific distinctive features ? The explanation which is considered to be the most satisfactory is provided by the principle of evolution. It suggests that the common plan of structure is based on common ancestry or descent. It is an indication of relationship. The closer the resemblances, the closer is the relationship. You will understand this idea better after reading something about evolution later in this book.

CHAPTER FOUR

The Body of Living Things

What Is an Organism?

A living thing is often described as a living organism. An organism is something that exhibits organization. All living things from the simplest plants and animals to the most complex, show various degrees of organization. Organization is an essential feature of all living beings.

When two or more units act in co-operation and harmony to attain a particular end, they are said to act in an organized manner. They can be described as displaying organization. A football or hockey team at play is a familiar example. Each organization consists of a group of different individuals co-operating with one another to achieve the common aim. Each member is a complete individual by himself or herself. But as member of an organization, each member subordinates his own individuality to a greater or lesser degree to co-operate with other members to achieve a common object which is the aim of the organization as a whole. When the co-operation and harmony of action and the oneness of purpose are perfect, the entire organization seems to act as one unit although in fact it is composed of so many different units.

A number of organizations with common or similar aims may combine together into one bigger organization to achieve some broader aim. In the case of an emergency such as an earthquake, a flood or a famine in the country, several social, political and religious organizations may co-operate together to provide relief to the sufferers. Thus a bigger organization is formed for the purpose of relief work. It acts as one body as far as this work is concerned. The smaller organizations that have merged are the units of this bigger organization. Each small organization has subordinated itself to some extent to fit itself into a bigger organization so that all may work in harmony. Thus, the same body can be looked upon as an organization consisting of individual members or units, and, also as one of the units of a bigger organization.

The harmonious correlation of parts or individual units, each performing one or more functions and contributing to the activities of the whole, is the essential feature of an organization. There is division of labour among the members and there is co-ordination of the actions performed by different members. Organization implies the presence of a co-ordinator or some co-ordinating mechanism like the captain of a team of players or that of a ship. For successful co-ordination efficient means of communication are necessary. Conditions from various parts have to be reported to the co-ordinator and the latter has to issue directions to one or more parts or members for necessary action.

Anything that exhibits organization can be called an organism. A motor car or a watch can be called an organism. But the organization seen in even the most complex non-living objects is simpler than that found in the simplest living organisms. Only living organisms are, therefore, usually described as organisms.

A living organism like a human being has organs such as hands and legs, eyes, nose, heart, lungs etc. Each organ itself is built up of several kinds of cells, there being many cells of each kind. All the cells of one kind in an organ form what is called a tissue. In higher organisms, therefore, we find different levels of organization. Cells are organized into tissues, tissues into organs and organs into the individual. In the case of the entire plant or animal body, organs are the units of organization; in the case of organs, tissues are the units; in tissues, cells are the units of organization.

All living beings consist of one or more protoplasmic cells. Protoplasmic cells are the units of their structure and organization. In the last analysis, the work of an organism is done in its individual cells. There are blood cells, nerve cells, muscle cells and so on, each kind specialized for a particular job, each kind helping others and at the same time profiting by this association. There is a unity of purpose in the actions of the various organs in a body, of the various tissues in an organ and of the cells in a tissue. A human body consists of numerous organs, a multitude of tissues and about a hundred million million cells. Yet the organization is so perfect that the body as a whole behaves as a single individual.

Organization in a Complex Animal Body

In a systematic study, the organization in the less evolved and simpler living organisms should be considered first. The organization in the more highly evolved or complex forms should then follow. But we are more familiar with higher plants and animals. So in studying organization we shall proceed in the order which is the reverse of the course of evolution.

As an example of higher animals we may consider man. Man belongs to the mammalian group of the vertebrates. Since related organisms possess a common fundamental plan, the description of organization in man will apply in broad outline to the vertebrates in general and to mammals in particular.

The human body has many organs. Some of the organs are more closely associated among themselves than with others. Such organs are collectively called organ systems. Each organ is designed for a particular job. At the same time each organ is dependent directly or indirectly upon others to a varying degree. No organ can work in isolation for any considerable length of time. And even during the short period when an organ may work in isolation, its work will not achieve what it does in the whole organism. The heart of an animal can continue beating for some time after removal from the body. But this continued beating cannot do what it does when the heart is part of the body.

Groups of organs in the human body can be regarded as forming the skeletal system, the muscular system, the breathing system, the digestive and nutritive system, the circulatory system. the excretory system, the nervous system, the endocrine system, and the reproductive system (FIG. 4). Besides these, there are many other organs such as the organs for seeing, hearing, smelling, taste, feeling by touch (the five senses) and speech etc.

The human body contains more than 200 bones which together form the skeletal system. They have three important functions, namely, protection, support and movement. The brain and the spinal cord are among the most important organs. They are also among the most delicate organs. The brain, at the top of the body, is completely protected within the hard, bony case called the skull. The vertebral column is built in an admirable way. It provides complete protection to the spinal cord and at the same time allows free movement. Ribs form a cage for housing delicate organs like the heart, the lungs, the liver etc. The bony frame in our bodies also gives support to other organs and muscles which are all soft.

The function of movement is carried out by bones in co-operation with the muscles. There are more than 600 such muscles in man. Bones and muscles are assisted by tendons in their work of movement.

The breathing system consists of the nose, the pharynx, the windpipe and the lungs. One may also include blood in the system. One can live for long periods without food or even water. But one cannot live without air even for a few minutes. The purpose of breathing is to get oxygen into the blood. This results in the release of energy which is needed for all kinds of activity of the body. As the air is inhaled and passes through the nose, it is cleansed. Dust particles and bacteria are caught by the hairs and the mucus in the nose that has germicidal properties. During its further passage, air is made warm and humid. This has been described as air-conditioning. The windpipe branches repeatedly into very fine tubes which end blindly in the lung. The lung is also provided with finely branched blood vessels. The ultimate branches of the windpipe come in contact with the fine branches of blood vessels. Through their thin membranous walls, the oxygen of the air in the windpipe enters the blood vessels while carbon dioxide in the blood passes out into the air.

The digestive and nutritive system is also very elaborate and complex. It is another model of co-ordination and interdependence of organs. The senses of sight and smell are not directly connected with nutrition and digestion. But we know that the sight and smell of delicious food stimulate the secretion of digestive juices. The mouth begins to water and the appetite becomes keener. The teeth chew the food. Taste glands in the tongue make it possible for us to enjoy the taste of food. The salivary glands secrete saliva which starts the first stage of digestion, changing starchy food into sugar. It also helps in swallowing the food. The food moves down the throat through a tube into the stomach. This tube performs the movements of alternate contraction and relaxation and thus pushes the solid food down.

In the stomach the food is slowly churned and mixed with a digestive juice. This juice digests mainly the proteins. From the stomach the food passes down into the intestines. Here it meets more digestive juice from the pancreas which can digest carbohydrates, proteins as well as fats. Bile juice from the liver helps in the digestion of fats. After the food has been changed into a form in which it can be absorbed by the intestines, it passes into the blood vessels which traverse the walls of the intestines. The blood then carries the digested food to all parts of the body. The part of the food that has not been digested or assimilated is passed out of the body as faeces (or dung).

The heart, the arteries and the veins constitute the circulatory system. They circulate blood throughout the body. The blood acquires oxygen in the lungs and food from the intestines. They are then circulated so that every part of the body, that is, every one of the cells in the entire organism, may get proper nourishment. The blood also circulates the hormones secreted by the endocrine glands. The carbon dioxide produced in various tissues is collected by the blood and passed out of the body through the lungs. Other waste matter collected by the blood is excreted through the kidneys with urine and through the skin with sweat.

An essential feature of organization is the presence of a co-ordinating system. In the human body, as in the body of many other animals, the co-ordinating mechanism consists of the nervous system which is made up of the brain, the spinal cord and a large number of nerves. The brain and the spinal cord together form what is called the central nervous system while the nerves constitute the peripheral nervous system. A stimulus applied to any part of the body is transmitted as a nerve impulse from that part to the central nervous system along the nerves. The response or reaction to the stimulus is then transmitted from the central nervous system, along the nerves, to the appropriate parts of the body which act in the desired manner. For example, the sight of food stimulates the nerves of the eye and the smell those of the nose. The taste of the food stimulates the taste glands in the mouth. These transmit messages to the brain which then sends appropriate messages to the various organs concerned for necessary action. The salivary glands respond to this message by beginning to secrete saliva which helps in the swallowing of the food and its partial digestion. Other organs of the digestive system similarly respond by beginning to perform their appropriate functions. The functioning units in the nervous tissues are the nerve cells or neurons. Their structure varies and is well adapted to their special functions.

The entire behaviour of an organism is controlled and co-ordinated by the nervous system. In its work of co-ordination the nervous system is assisted by a number of glands which constitute the endocrine system. These glands secrete into the blood chemical substances of great potency called hormones. Extremely small quantities of hormones can produce remarkable results. As an example may be mentioned the adrenal glands situated near the kidneys. They secrete the hormone called adrenaline which prepares the body for vigorous action in case of an emergency. Each hormone is characterised by its own function but the various hormones act in harmony. The final result depends upon the interaction between various hormones which themselves are controlled by the nervous system.

The simplest organisms have no visible nervous system. Organisms a little higher in the scale of evolution than the simplest ones have a simple nervous system. The human body possesses the most highly evolved and complicated nervous system. It is specially characterised by a high degree of evolution of the brain both structurally and functionally. It is the high level of evolution of the human brain that gives man the ability to think, to reason, to plan and to solve problems. It is the characteristic development of the human brain that makes him an intellectual being, a wise being or the *Homo sapiens* although, unfortunately, he does not always behave wisely.

It is not possible to deal with all the organs in the body in a short space. Even the organs that have been mentioned above have been described in an extremely sketchy manner. But even this short description gives some idea of the complexity of organization.

Organization in a Complex Plant Body

Among plants, the flowering plants form the most highly evolved and complex group. They are also the most familiar plants to us. The differences between the most highly evolved animals and the most highly evolved plants are very striking. This may lead one to think that the two are fundamentally different. But when we study the organization of simpler plants and animals, we shall see that the two groups converge till we approach organisms which can be called plants as well as animals.

A flowering plant such as that of wheat, mustard, pea or mango has certain essential organs. These are the roots, the stems, leaves, flowers, fruits and seeds. Each of these organs is specialized for some special job in addition to some general activities. The roots usually grow into the soil. The part of the plant growing into the air is called the shoot. The roots, stems and leaves are primarily concerned with the collection, synthesis and assimilation of food and with growth. They are called vegetative organs. The flowers, fruits and seeds are primarily concerned with reproduction and are called reproductive organs. The flower actually consists of several organs and may be described as an organ system. Fruits and seeds are produced by the flowers (FIG. 5).

Traversing the entire plant body from one end to the other, entering into all the branches of the root and the stem and every leaf, is the conducting system. This is comparable, in a way, to the circulatory system of arteries and veins in animals although there is nothing in plants like the heart in higher animals. Plants also have their hormones but the regions producing them are not so conspicuously marked out as the endocrine glands in animals.

The primary work of the roots is to get food from the soil and pass it on to other parts of the body of the plant through the conducting system. They also fix the plant to the soil. Plant food is available in the form of mineral salts dissolved in water. The roots are specially designed for absorbing it. The roots send out many branches which traverse as wide an area as possible. The region of absorption is near the tips of the roots. Here, the cells on the surface are specially built to absorb solutions. Each cell grows out into a long tube called a root-hair. This makes the cell not only an efficient absorber but also enables it to utilize a larger area of soil. Under a magnifying lens, the entire absorptive region looks like a bottle-brush, the elongated tubular cells looking like bristles. The absorbed mineral solution passes from cell to cell till it reaches the inner region where conducting elements are situated. It then enters one kind of conducting cells which form the tissue called xylem. Through xylem cells the solution moves upward into the stem and into every branch and leaf right to its tip.

The stem supports the various organs of the plant, holds them in proper position and connects them with one another and with the roots. The leaf is a very remarkable organ. Its importance depends upon its green matter, the chlorophyll. The cells in the leaf that contain chlorophyll have the ability to transform the carbon dioxide of the atmosphere into sugar in the presence of sunlight and water. Later, this sugar and the mineral substances absorbed by the root are elaborated further into more complex substances. The elaborated food substances move from the leaf to all the other parts of the plant body through the second type of conducting cells which form the tissue called phloem. The elaborated food substances are used by the plant in various ways, one of which is their transformation into the living substance or protoplasm.

The synthesis of food from simple substances in the presence of sunlight is called photosynthesis. It takes place usually in the leaf. The leaf is the primary food factory of nature. Or, to be more precise, the chlorophyll-containing cells are the food factories of nature. Animals in general are without chlorophyll. They cannot manufacture food as the plants can do. Animal life is, therefore, dependent upon plant life. The chlorophyll-containing cells in general, and the chlorophyll-containing tissues of the leaves in particular, are the primary source of food. Their fundamental importance for the existence and maintenance of life is obvious.

Plants absorb much more water through the roots than they need. The excess is lost mainly through the leaves. This process is called transpiration. Respiration, i.e., taking in oxygen and giving out carbon dioxide resulting in the release of energy, takes place throughout the entire body of the plant and there are no specialized organs for this purpose. Plants have their own mechanism of responding to stimuli.

The above description is also applicable to pines and cycads and their relatives with the difference that although they have seeds, they have no fruits and flowers in the sense in which they are usually understood. Ferns and some other plants do not even produce seeds. In their vegetative body, however, they also display the same fundamental organization into roots, stems and leaves as flowering plants.

Organization in a Simple Body

As an example of a simple animal we shall study *Hydra*. It is a small animal, about one fourth of an inch in length. It is an invertebrate, that is to say, it has no backbone. In fact it has no bone at all. There are many other things it does not have. It has no legs or hands and it has no head or tail. It has no eyes, ears, or nose. It has no heart or lungs and it has no arteries or veins or blood. It has no liver, no kidneys, no pancreas, no intestines and no bladder. It has no brain or spinal cord or nerves. You might be just at the point of exclaiming, " Why don't you tell us what it has instead of giving a long list of what it hasn't." Well, it has a stomach and a mouth although the mouth has neither lips nor teeth nor tongue.

The entire body of *Hydra* may be compared to a long, narrow bottle with a hole at the top. The hollow space of the bottle is the stomach and the hole at the top is the mouth. Around the mouth are seen six to ten hair-like processes called the tentacles. These are like fine tubes and their hollow spaces are continuous with the cavity of the stomach (FIG. 6).

Hydra lives in water. Its lower end may be seen to be attached to some object and the animal may appear to be fixed. But it can " walk " by gliding over the surface of its support or by imitating the movements of certain worms. The tentacles perform sweeping movements in water, catch minute animals and plants and pass them on to the mouth. These enter the stomach through the mouth and become the food of the animal. They are digested and absorbed in a soluble form. The undigested portion is thrown out through the mouth.

In *Hydra* the organization is so simple that there are few organs and no organ systems. There is little specialization in the structure of organs or tissues. *Hydra* being small and transparent, its cells can be seen under a microscope without any section-cutting or dissection which is usually necessary in the case of larger organisms. The entire body has simply two layers of cells. The outer layer is in contact with water in which the animal lives.

The inner layer lines the hollow space inside. Between the two layers of cells is a layer of jelly called mesoglea. There is no circulatory system. All the cells absorb their food either directly from the stomach or through diffusion from cell to cell. Every cell has to absorb its own oxygen directly from the medium in which it lives. Similarly, carbon dioxide is discharged directly from each cell. Some cells are modified to act as nerve cells, others aid in protection or in catching the prey and still others create water currents in the stomach to facilitate the movement of food particles. These specialized cells, however, are scattered all over. They are not organized into separate tissues or organs.

There are many organisms much simpler than *Hydra*. For instance, in some algae (alga is singular, algae plural) the entire body is just like a slender thread or filament. These organisms do not have even a mouth or a stomach, not to speak of anything else. The filament is made up of just one row of cells. The cells, as the units of body structure, have been compared to bricks. In these algae you might imagine the body as consisting of a row of bricks placed end to end. Since the filaments are cylindrical, it might be better to imagine a number of minute barrels, instead of bricks, placed end to end. In some the barrel-like cells are long as in *Spirogyra*, the " pond scum " or " the pond silk." In others the barrels may be short as in *Ulothrix* (FIG. 6).

Plants like *Spirogyra* and *Ulothrix* are so simple that they have neither organs nor tissues. All the cells in the filament may be alike. In such cases each cell is capable of performing all the vital activities. There is no differentiation either in the structure of cells or in their functions. There is no division of labour among the different cells. Some of the plants may grow attached to some object. In these, the cell at the attached end may be different from other cells. This end of the plant may then be called the base and the other end the apex. In the unattached filamentous algae, which float in water, it may not be possible to distinguish even the base and the apex.

In algae like *Ulothrix* and *Spirogyra* the organization of cells is seen only in the cells being joined to one another. Each cell functions independently although it is not considered a separate individual. But the individuality of the plant as a whole is also vague. There is no differentiation of any kind, the two ends also are not different and even the number of cells in the filament is not definite. Break a single filament into several pieces and each piece will live and grow and reproduce as merrily as the original filament would have done. Thus you may produce several individuals from one, simply by breaking it into pieces. The degree of interdependence of the component units or cells has been reduced to a minimum. Each cell in such organisms has relatively greater importance than in higher organisms while the individuality of the organism as a whole is less marked. Individuals with such vague and indefinite individuality are often called colonies (of cells) instead of individuals.

The extreme simplicity of organization is seen in organisms consisting of just one single cell. *Amoeba* and the malarial parasite have already been cited as examples of one-celled animals. Bacteria and many algae are one-celled plants. One such alga, namely, *Protococcus*, forms a green coating on walls and tree trunks in the rainy season. It is one-celled but often grows into groups of 2, 4, 8 or more cells forming small colonies. If the cells in the group are separated from one another, each cell lives as an individual as if nothing had happened. *Euglena* is a one-celled organism, containing chlorophyll or the green colouring matter of plants, and it has the ability to move. It is classified both as a plant and as an animal (FIG. 6).

CHAPTER FIVE

The Cell

Structure of Cells

A complex body is made up of many organs, organs are made up of tissues and, finally, tissues are made up of cells. What are cells? Are cells the ultimate units? Or, do cells also exhibit organization capable of further analysis?

A cell is one of the greatest wonders of nature. Cells are usually very small. Yet, they show a highly complex organization. And the variety of chemical activity that goes on within these tiny bits of matter has amazed the greatest chemists. The delicate setting of all the organs in a complex body like that of a human being, and the efficiency and harmony seen in their working, appear crude as compared with the organization seen within a cell.

Cells vary in size and shape. They may be spherical, oval, polygonal, disc-shaped, elongated like a fibre, tubular or barrel-shaped. Sometimes they are best described as irregular (FIG. 7). An oval cell may be compared to a bird's egg in having three main regions. The egg has a shell which contains the white of the egg surrounding the yolk or yellow body which is situated more or less centrally. The outer cover of the cell is called the cell wall. The matter next to the cell wall is called the cytoplasm and the central body which it surrounds is called the nucleus. The cytoplasm and the nucleus are simply two forms of living matter and the two together constitute protoplasm. The cell wall is merely protective; it is a product of the living matter and not a part of it. It is not an essential part of the cell. The essential part is the protoplasmic body inside the cell wall often called the protoplast to distinguish it from the cell as a whole. The nucleus is an important part of protoplasm. An experiment with amoeba, a one-celled animal, shows this very clearly. The amoeba reproduces by dividing into two cells which separate and live independently as two individuals. In course of time these two grow and then divide into four separate individuals. This is repeated indefinitely and the number of amoebae multiplies. An amoeba can be cut experimentally into two parts so that one contains the nucleus and the other is without it. When this is done, the part without the nucleus does not live long nor does it multiply indefinitely. It may divide once or twice but the cells without the nuclei die within a few days. On the other hand, the part containing the nucleus goes on multiplying indefinitely.

The cytoplasm may be described as a gelatinous fluid. Its outer part forms an extremely thin membrane called the plasma membrane. The remaining cytoplasm is called the cytolymph. The cytolymph has spaces or vacuoles filled with watery solutions described as the cell sap. These vacuoles are also lined with the plasma membrane. The cytolymph shows a variety of small bodies scattered in it. Some of these are living, others non-living. The nucleus is usually spherical or oval in shape. It consists of two parts. The outer is the nuclear membrane surrounding the inner fluid contents called the karyolymph. The karyolymph shows one or more prominent oval or spherical bodies called nucleoli (plural of nucleolus).

The structure of the cell can be understood easily by observing a single-celled organism. Put a small drop of water from a pond or a drain on a glass slide and observe it through a microscope. You will find the drop of water swarming with life. You might find in it one-celled organisms like *Euglena* (plant-animal), *Chlamydomonas* (a plant), *Paramoecium* and *Amoeba* (animals), several kinds of bacteria etc. Cells can be observed easily in filamentous algae too. Put on the glass slide, in a drop of water, a few filaments of the pond-silk or pond scum (*Spirogyra*). You will see each filament consisting of cylindrical cells placed end to end. Each cell will show a prominent nucleus and a beautiful chloroplast which is in the form of a spiral band (FIGS. 6 and 7). In the higher organisms cells usually form compact tissues which build up organs. To see them one has to cut the organs and tissues into thin slices which are then examined under a microscope. One can also employ methods of separating the cells in a tissue from one another. Blood cells can be seen without any cutting or dissection because they float loosely in a fluid medium. Cells lining our cheeks are also easy to see. Scrape the inside of your cheek with some blunt object, say, a toothpick. Examine the scraping under a microscope. Observation of the cells composing muscles, bones or nerves needs elaborate preparation (FIG. 7). The skin of a leaf can be peeled off and its cells seen without much difficulty. But in order to see the cells of the inner tissues you have to cut a section (FIG. 8).

The Living Matter

The chemical analysis of the protoplasm shows that it is made up of elements which also occur in nature in the non-living world. 80 per cent of protoplasm consists of water which is made up of the elements hydrogen and oxygen. These two elements together with nitrogen and carbon make up 99 per cent of protoplasm. The remaining part is made up mostly of eight other elements, namely, phosphorus, sulphur, potassium, magnesium, iron, sodium, chlorine and calcium. Traces of a few other elements are also present in the protoplasm.

Among the chemical compounds in the protoplasm water is not only the largest component but also one of the most important. It is in the medium of water that substances exist in a dissolved or suspended state. And it is in the medium of water that various chemical activities take place. Water has therefore been described as the substratum, the medium and the background in and against which the drama of life is unfolded. In addition to water, protoplasm contains proteins including enzymes, fats and fatty substances, carbohydrates and inorganic substances.

Proteins are highly complex substances. They are of many kinds. Except water, they are the most important chemicals in protoplasm. They are specially abundant in the nucleus. Certain complex proteins occurring in protoplasm are called enzymes. They have the ability to bring about chemical reactions. These reactions, in the laboratory, may require the use of powerful agents and very high temperatures. Enzymes can bring about the same reactions in protoplasm without any considerable change in temperature. They bring about chemical changes but they themselves remain unchanged. Enzymes are produced only by living cells. Most enzymes are specific in their action. One enzyme promotes only one or only a few similar reactions. Enzymes are essential for living matter. The number of different enzymes that may be contained in a single cell has been estimated to be at least a thousand.

Think of the size of an ordinary cell and then think of the number of enzymes, the various kinds of proteins, fats, fatty substances, carbohydrates and inorganic substances in it. And finally think of all the reactions going on within this tiny bit of matter, a protoplasmic cell, without any flasks or test tubes, without furnaces or burners and boilers and without any chemist to plan and to guide the reactions. Can one imagine such a wonderful chemical laboratory existing anywhere outside the living organism?

The Cell as the Unit of Organization

Cells are regarded as the units of structural organization in living beings. The fact that the bodies of all organisms consist of cells and their products is described as the Cell Theory or the Cell Principle. An organism may be one-celled. Even when the body is many-celled, most organisms at one time or other pass through the one-celled state. Thus, every human body, consisting of a thousand million million cells, starts life as a single cell. The original, single cell divides into two cells. These two cells divide into four, the four cells into eight and so on. These cells multiply and grow together. What was a mere speck of protoplasm, in time grows into a fully developed adult human being. In the unicellular organisms, when the cell divides into two, the two daughter cells separate and live as two separate and independent one-celled individuals.

In the multicellular organisms of some degree of complexity the cells are organized into tissues and the tissues into organs. Let us consider a leaf as an example (FIG. 8). A leaf is one of the organs of a plant. It is made up of many cells organized into a number of tissues. For example, one such tissue is the skin (epidermis) of the leaf. It consists of a single layer of cells similar to one another but different in form from those of other tissues. The skin is provided with pores for the entry and exit of gases and water vapour. Each pore (stomate) is surrounded by two cells which regulate the opening. Within the skin there are usually two tissues of cells containing the green matter of the leaf, the chlorophyll. On one side of the leaf, the upper side in a flat leaf, the cells containing chlorophyll are elongated and stand side by side at right angles to the leaf surface. They are compactly arranged and constitute what is called the palisade tissue. On the other side the chlorophyll containing cells are irregular in shape and form a spongy tissue. All the cells of the spongy tissue are of one kind. All the cells of the palisade tissue are of another kind. All the cells in the skin, except those surrounding the pores, are alike and of a third kind. The conducting (or the vascular) system, seen externally as a network of veins, consists of complex tissues ; they are made of more than one kind of cells. All these tissues together make up the organ, a leaf in this case. This leaf together with other leaves and the roots, stems, flowers, fruits and seeds makes up an individual plant. In animals as well as in plants, cells form tissues, tissues form organs and organs make up the individual. The cells are thus the units of organization.

The Cell as the Functioning Unit

The cell is not only the unit of structural organization in living beings but it is also the functioning unit. It is potentially capable of independent existence structurally as well as functionally. This phenomenon is best seen in one-celled organisms. A one-celled organism performs all the essential functions including reproduction.

In simple multicellular organisms like *Spirogyra* all the cells may be alike. Every one of the cells carries on all the activities of life and is therefore a functioning unit. In more highly evolved organisms there is an increasing degree of specialization. Every individual cell does not perform all the activities. As it becomes more and more specialized it loses some of its general activities. The cells in the leaf cannot absorb food from the soil while the cells in the roots cannot perform photosynthesis. But whatever may be the function of an organ or a tissue, it is, in the ultimate analysis, performed in its individual cells. The digestive system consists of many organs but in each case it is the cells in every organ that do the real work. It is cells that secrete digestive juices or absorb digested food. In the nervous system it is the nerve cells that transmit nerve impulses. Similarly this is true of all organs and all tissues.

Inside the organized body of an individual, the various life activities of the organs are being performed inside the individual cells. This is more or less like an army on the march. When the army as a whole is moving, it is actually every individual soldier who is moving. The march of the army as a whole is simply the sum-total of the movement of its individual units, the soldiers. A soldier can march alone. As a unit of the army he has to do it in harmony with others. Similarly the cell is a functional unit. Inside the organism it performs its functions as a unit in co-operation and in harmony with other units.

CHAPTER SIX

Reproduction

Sexual Reproduction

Reproduction is the most important distinctive feature of living organisms. They alone can produce more living beings like themselves. The birth of babies and their growth into adults like their parents and other human beings are familiar occurrences. It is also known to every one that in many animals the birth of a baby is preceded by the union or mating of two individuals, a female and a male. This distinction of individuals into female and male is known as sex. Sex differentiation is not limited to externally visible organs. In the male the internal sex organs are the testes which produce the male sex cells or male gametes also known as sperms or spermatozoa (singular spermatozoon). They are so small that a single drop of seminal fluid may contain 100,000,000 sperms. In shape the sperm is more or less like a worm with a small head and a long tail. In the female the internal sex organs are the ovaries. These produce the female sex cells or the female gametes also known as ova (singular ovum) or eggs. A human ovum is many thousand times larger than a sperm, yet it is just visible to the naked eye. It is spherical in shape and has a diameter of about 1/8th of a millimetre (FIG. 9).

Mating leads to the union of one male sex cell or sperm with one female sex cell or ovum in the body of the female. This union is permanent. It is called fertilization. In this process the nucleus of the sperm unites with the nucleus of the ovum. The union of the two sex cells is so intimate that the product of their union is a single cell with a single nucleus. This single cell, called the zygote, is the starting point of the development of a new individual.

The zygote, situated in the womb of the female, divides into two cells which do not separate from each other. The two cells divide into four, four into eight, eight into sixteen and so on.

All the cells remain together forming a small body. As the number of cells increases, the body as a whole increases in size. This is the embryo, that is, an individual in its early stage of development before birth. With further development, one may see the beginning of organ formation. As growth and differentiation proceed, the human embryo gradually assumes the form of a baby. At a particular stage of development, which takes about nine months from the time of fertilization, the embryo comes out of the mother's body. A baby is born (FIGS. 10 and 11).

In a flowering plant like the date palm some trees are male, others female. The male trees bear male flowers which contain the male organs, the stamens. The female trees produce the female flowers which contain the female organs, the carpels. Most flowering plants are bisexual, bearing flowers which contain both stamens and carpels.

The stamens produce a powdery substance which consists of very small grains known as the pollen grains. These grains produce the male gametes or sperms. The basal part of the female organ is the ovary which contains one or more small, oval or spherical bodies called the ovules. The ovule contains the female gamete known as ovum or egg. The pollen grains are carried to the female organs by wind, birds, bees, butterflies etc. They are deposited upon the top of the female organ or the stigma. Here the pollen grains produce long tube-like structure. These pollen tubes penetrate into the tissues, enter the ovary and release the sperms into the ovules near the female gametes. (FIG. 12) A sperm fuses with an egg, the nuclei of the two uniting to form one nucleus. Thus a zygote is produced which develops into an embryo. The ripe ovule containing the mature embryo is the seed. The ovary containing the seeds develops into fruit. When the mature seed is placed in suitable conditions, the embryo starts growing and develops into a new plant (FIG. 13). The mature seed is comparable to the fertilized and mature egg of a bird. The new plantlet comes out of the seed just as the little bird hatches out of the egg.

Variety in the Methods of Reproduction

The method of reproduction as described above is not the only one. Both in animals and plants the essence of sexual reproduction is the union of a male sex cell with a female sex cell. In other features of sexual reproduction there is a great variety. For instance, the union of the sex cells may occur in water outside the body of the female, as in the frog, and not inside the body as in mammals. Some animals and many plants are bisexual, the same individual having both the male and female organs. In simple organisms like *Spirogyra* there are no sex organs. Sexual reproduction in *Spirogyra* occurs simply by the union of the contents of one cell with those of another in the same filament or in a different filament.

The increase in the number of cells as seen in *Amoeba* is called asexual reproduction. Many animals and plants are capable of producing new individuals from portions of their bodies. Propagation of plants from cuttings is a common practice. This is often described as vegetative propagation. Something similar can happen in *Hydra*, some worms, starfishes etc. In *Hydra* and some other animals, new individuals may grow out from the body of the parent more or less like buds or branches growing on a plant. Many plants and animals can reproduce both sexually and asexually.

Cell Division and Reproduction

The fact that cells divide and increase in number has been mentioned repeatedly in different connections. In the process of fertilization there is fusion of two cells into one. It is now necessary to go a little further into this behaviour of cells.

The division of a cell into two reveals the great importance of the nucleus. It is preceded by a series of changes in the nucleus. The result of these changes is that the nucleus, which was a round or oval body, becomes resolved into a number of thread-like structures called chromosomes. They are very important things and you should, therefore, carefully remember the name. The number of chromosomes that is seen at this stage is usually definite and fixed for every species of animals or plants. For instance, in man the nucleus is transformed into 23 pairs of chromosomes. In one species of crayfish there are 100 pairs of chromosomes, in the fruit fly 4 pairs, in some wheats 21 pairs, in maize 10 pairs and in *Ascaris*, a roundworm, only one pair.

Note that the numbers of chromosomes are given above in pairs. This is significant. Careful study has shown that usually the ordinary body cells have two chromosomes of each kind. In man there are forty-six chromosomes. They are not all alike. Each chromosome has its own individuality by which it can be recognized. The forty-six chromosomes of man are of twenty-three different kinds, there being two of each kind. In the fruit fly there are eight chromosomes of four different forms, there being two of each form. You can yourself explain why there are two chromosomes of each form or kind and why not only one or three or five. You will recollect that the first cell from which an individual develops, that is, the zygote, is really double in nature. The nucleus of the zygote is similarly double in nature. It is the product of the fusion of two nuclei. In man the sperm nucleus has 23 chromosomes, one of each kind. The ovum nucleus similarly has 23 chromosomes, one of each kind, like those of the sperm. The zygote nucleus will obviously have 46 chromosomes, two of each kind, or twenty-three pairs.

All cells in the body are derived from the zygote, which is the original or the first cell of the body. And, all cells in the body contain the same number of pairs of chromosomes as the zygote until a change occurs when sex cells, the ova and the sperms, are formed.

When a human zygote is about to develop into two cells, its nucleus becomes resolved into 46 chromosomes. At a certain stage, every one of the 46 chromosomes is seen to have become doubled (See FIG. 14 a and b. Only six chromosomes have been shown for the sake of clarity). This means that every one of the original chromosomes has given rise, in its place, to two new daughter chromosomes which may be seen coiled along each other. A spindle like structure is seen in the cytoplasm at about this time. The 46 chromosomes or, to be precise, now the 46 pairs of daughter chromosomes become arranged in a plane along the middle of this spindle (FIG. 14 c). The two daughter chromosomes formed from each of the original chromosomes separate and then move in opposite directions. This leads to the formation of two groups of daughter chromosomes placed at the two ends of the spindle. Each group consists of 46 daughter chromosomes which have become, by now, full-fledged chromosomes (FIG. 14 d).

The 46 chromosomes of each group become organized into a new nucleus. Two new nuclei are thus formed. A wall begins to develop in the middle of the cell, between the two daughter nuclei and the spindle disappears. The original cell, the zygote in this case, thus becomes divided into two new cells (FIG. 14 e and f). Each new cell has its own nucleus which consists of 46 chromosomes, or 23 pairs, like the zygote nucleus from which it is derived.

Just as the zygote divides into two new cells, the two new cells divide into four cells. Each of the four cells divides into two again and in this way the number of cells goes on increasing. At each division the entire process described above is repeated with remarkable precision. The nucleus of every one of the new cells has got the same number of chromosomes as the original zygote, that is, 23 pairs. And it is to be noted that these twenty-three pairs are exactly like the twenty-three pairs in the zygote in size, shape, structure and behaviour.

A variation in the method of division is noted when sex cells are produced. A cell divides into two and then into four, but the chromosomes divide only once. The doubled number of chromosomes is shared not by two cells but by four new cells. How many chromosomes will there be in each of the four cells? Twenty-three is the obvious answer. The original 46 chromosomes become 92 which are distributed to four new cells, each getting 23. Each sex cell thus gets half the number of chromosomes present in the ordinary body cell or the zygote. The human sex cells contain only 23 chromosomes, one of each kind. This division resulting in reduction of the number of chromosomes is called reduction division (FIG. 14 g-m. Only three pairs of chromosomes have been shown for the sake of clarity). At the time of fertilization, when a male and a female gamete unite, the new zygote again has the 23 pairs like the zygote of the preceding generation.

Every sexually reproducing individual starts with a zygote which has two sets of chromosomes. It is the result of fusion of two sex cells each with a single set of chromosomes. In each generation, there is regular alternation of the occurrence of one chromosome set in the sex cells and two chromosome sets in the ordinary body cells. It is the result of regular alternation of reduction division and fertilization at fixed stages in the life of individuals reproducing sexually.

It has already been pointed out that chromosomes have individuality. This individuality is retained during the repeated cell and nuclear divisions. It is due to the fact that when a chromosome divides into two daughter chromosomes, the daughter chromosomes are exactly like the chromosome which produced them and therefore also exactly like each other. In the sex cells of an individual the same 23 kinds of chromosomes can be recognised which were present in the sex cells of his or her parents. Again, in the new zygote which will develop into an individual of a new generation, one can recognize the same kinds of chromosomes in the same number as in the zygote of the preceding generation. The chromosomes retain their individuality not only from cell to cell in the body of any one individual but also from one generation to another. The chromosomes present in the nuclei of an individual are like the chromosomes that were present in the bodies of his or her parents, grand-parents, great-grand-parents and other ancestors. It is obvious that individuals who have descended from common ancestors, that is, individuals who are related to one another, will have similar chromosomes.

CHAPTER SEVEN

Heredity

The Meaning of Heredity

If you sow a mango seed you are quite sure that it will grow into a mango tree and not into an apple tree or a rose bush. Wheat grains always produce wheat plants and not barley; and barley grains always produce only barley plants and not wheat or, for that matter, any other kind of plant. When the eggs of a fowl hatch, they produce only fowl. The offspring of dogs are always dogs and not wolves or jackals or cats. Like all other living beings, human beings produce only human children. This tendency of living things to pass on their characteristics to the following generation, resulting in resemblance between parents and children, is called heredity.

Let us probe the matter a little further. All mangoes are not of one kind and all human beings are not alike. There are varieties and races within species. A mango seed does not grow into a mango tree of any or every kind; it grows into a mango tree of that particular variety alone which produced the seed. The children of the Zulus are not only human but also Zulus. They will grow into Zulus and not into American Indians or Mongolians. You will also note that a child is like its parents not only in being human and in belonging to a particular type of human beings but also in certain matters of finer detail.

What is the cause of the resemblance between parents and offspring ? Why does a mango seed produce a mango tree and not something else and why do human offspring always grow into human beings and not into any other kind of living beings? The only possible answer is that a mango seed always produces a mango tree because it is a mango seed; the offspring of human beings are always human because they are the offspring of human beings. "This is no answer !", you will perhaps say. Let us, however, be content with it for the present; we shall elaborate the point later.

HEREDITY

Resemblances between parents and offspring are common. Equally common and noteworthy are the differences or variations between parents and offspring and among offspring of the same parents. Every individual has its own distinctive features in which it is unique and, at the same time, it has features in which it resembles others and which make it a member of a particular group. The branch of biology which deals with the study of these resemblances and differences or the phenomena of heredity and variation is called genetics.

Biological Inheritance and Chromosomes

The development of the entire personality of an individual is the result of interaction between two sets of factors : the inherent, the inborn, the hereditary or, speaking more precisely, the genetic factors and the environmental factors. Environment is a very comprehensive expression and includes the totality of the conditions of life. You may distinguish between internal and external environment. The various conditions within the body constitute the internal environment. The external environment includes the geography, climate, social conditions, education and training. clothing, food etc. When it is said that a certain feature, character or trait of an individual is hereditary or genetic, the meaning is that the individual has the potential ability of exhibiting that feature, character or trait under suitable environmental conditions.

The intimate relationship between certain characters of individuals and their parentage is obvious. How do parents ensure that their children will inherit their characters and qualities? When parents want that their children should inherit their property, they can execute a will which has legal sanction. But what can parents do when they wish that their sons and daughters should have fair skin, lovely faces, charming eyes or curly hair like themselves? They simply can't call a lawyer and dictate a will. Neither are children made of wax or other plastic substances that could be moulded as desired by the parents. The mechanism of biological inheritance is quite different. The only physical or material link between the parents and their children is a male cell from the father and a female cell from the mother. Whatever the child inherits from its two parents comes in these two cells. And if we want to know how it is that parents determine the genetic potentialities of their children, we should probe into those two wonderful cells. Those two cells, like all other cells, contain cytoplasm and nucleus. The nucleus consists of chromosomes. Chromosomes carry the factors that are responsible for the phenomenon of heredity. These factors are also known as genes. It is the chromosomes with their genes that constitute the genetic factors for the development of an organism.

A few examples will suffice to illustrate the relation between the chromosomes and the characters of organisms. You already know that the individuals of each species have a definite chromosome number. *Ascaris* has one pair, fruit fly 4 pairs, onion 8 pairs, maize 10 pairs, *Spirogyra* 12 pairs, pine 12 pairs, trout 12 pairs, man 23 pairs, horse 30 pairs, crayfish 100 pairs etc. Of course the number of chromosomes alone does not define a species. *Spirogyra* and pine, plants so different from one another, and trout, an aminal, all have the same number. But whatever the number, it is definite and usually invariable for all the individuals of that species. (Departures from this generalization will be considered later.) More important than the number of chromosomes is their structure. Each chromosome has a distinctive structure which marks it out as an individual different from others. The kinds of chromosomes and their number together make the genetic constitution of an organism.

Some species include varieties or races with different characters and they also have different chromosome numbers. A species may include a race which has four chromosomes of each kind instead of only two of each kind. These have thus four complete sets of chromosomes. Plants with four chromosomes of each kind instead of two can be produced artificially from ordinary plants comparatively easily with the help of a chemical substance called colchicine. This change in chromosome number produces a distinct change in the various characters of the plants. Such plants occurring naturally or produced artificially have not only larger nuclei and cells but, in general, larger organs than ordinary plants. They have larger leaves, flowers or fruits. Occasionally an exceptional individual occurs in which some parts of the body have the usual two chromosome sets and other parts of the body have four sets. And when this happens, the parts of the individual with different chromosome numbers have different characters. There are other variations in chromosome number within a species and these are usually associated with variation in characters of the organisms concerned.

The sex of an individual also depends upon the chromosomes. As an example, let us consider the fruit fly with 4 pairs of chromosomes. In the female fruit fly, the two members of each of the 4 pairs are like each other. In the male, the members are like each other in three out of the four pairs. The fourth pair consists of two unlike members. This pair of chromosomes in the male is therefore distinct from others in this respect. One member of this pair is like the two members of the corresponding pair in the female. These similar chromosomes, two in the female and one in the male, are called X-chromosomes. The mate of the X-chromosome in the male, being different from it, is called the Y-chromosome. The sex of an individual depends upon the ratio of the X- and Y-chromosomes to the ordinary chromosomes. Ordinarily, the female fruit fly has 3 pairs of ordinary chromosomes and one pair of X-chromosomes while the male fly has three pairs of ordinary chromosomes and one pair consisting of one X-chromosome and one Y-chromosome (FIG. 15).

The mechanism of sex determination in man is similar to that in the fruit fly. Other organisms show variation but the fundamental fact of the relationship of sex to chromosomes holds in their case as well. In bees some ova develop after fertilization while others develop without being fertilized by a male sperm (the phenomenon of virgin birth). The individuals developing after fertilization have the usual two sets of chromosomes and they are all females. The individuals developing without the union of sperms would obviously have only one set of chromosomes, the set contributed by the mother. Such individuals are all males.

In the fruit fly exceptional individuals are occasionally found in which half the body on one side is female and the other half is male. When the chromosomes from the two sides of the body are examined it is found that each side contains the kinds of chromosomes that you would expect on the basis of the explanation given above.

The examples cited above are quite adequate to impress upon you the intimate relationship between the characters of individuals and the chromosomes which they receive from their parents through the sperm and the ovum. All that an organism inherits from its parents is a sperm and an ovum with their chromosomes. The chromosomes, with the genes carried by them, provide all the innumerable potentialities of our entire development and behaviour which may find visible or invisible expression at different stages during the course of our life. We do not inherit organs or tissues or characters and features as such. What we inherit is simply the potentiality to develop in a certain way in a certain environment.

CHAPTER EIGHT

The Mechanism of Heredity

The Principle of Segregation

The first scientific study which became the foundation of the new science of genetics was made by a religious man, Gregor Johann Mendel (1822-84), a monk in a monastery at Brünn, Austria (now Brno, Czechoslovakia) (FIG. 16). He published his epoch-making conclusions in the year 1866. The scientific world at that time was not prepared to appreciate the great importance of Mendel's work. It was only 16 years after his death, in the year 1900, that biologists discovered and appreciated his paper published in 1866. Mendel's conclusions, known as Mendel's laws or principles, are well-known today and are often referred to as *Mendelism*.

Mendel's studies were based on his experiments with peas. We shall, however, consider an animal, the fruit fly, as an example to illustrate his principles. Fruit flies vary in eye colour. There are red-eyed fruit flies, brown-eyed and white-eyed. If a certain type, mating with its own type, produces in subsequent generations only individuals of its own particular type, it is called pure-breeding or true-breeding. When a pure-breeding red-eyed fly, say a male, mates with a pure brown-eyed female, all the flies of the first generation are, without exception, red-eyed (FIG. 17). If these red-eyed flies mate with one another, they produce offspring in which approximately 3/4 of the flies are red-eyed and approximately 1/4 are brown-eyed (FIG. 18). All the brown-eyed flies are pure like the brown-eyed grandparent; if they mate among themselves, they produce only brown-eyed offspring. Among the red-eyed flies of the second generation all are not pure. About 1/3 of them are pure like the red-eyed grandparent. The remaining 2/3, mating among themselves, produce in their offspring approximately 75 per cent red-eyed and 25 per cent brown-eyed flies.

When red-eyed and brown-eyed parents mated and produced only red-eyed children in the first generation, the brown-eye character was prevented from manifesting itself but it reappeared in the second generation. In such cases when one hereditary factor prevents the expression of the other in this manner, it may be called dominant and the other, whose manifestation has been temporarily prevented, recessive.

On the basis of Mendelian principles the inheritance of eye colour in fruit fly, in the above example, is explained as follows. Every cell in the body of the pure red-eyed male parent carries a pair of hereditary factors or genes for red-eye colour. But when the sperms are formed, the two members of the pair separate or segregate so that each sperm receives only one factor or gene for red-eye colour. Every cell in the body of the pure brown-eyed female parent carries, similarly, a pair of genes for brown-eye colour but each of the ova produced by it gets only one gene as a result of separation or segregation of the two forming the pair. (This is Mendel's principle of segregation.) The zygote is the result of the union of one such sperm with one such ovum. The gene pair for eye colour in it, therefore, consists of one gene for red-eye colour and one for brown. The zygotes will develop into red-eyed individuals because the gene for red-eye colour is dominant. These individuals produce gametes each of which will contain only one gene for eye colour. Since, in this case, the gamete producing individuals have the two genes of different kinds, there will be two kinds of gametes. Approximately half the sperms produced by the males get the gene for red-eye colour and the remaining half the gene for brown. Similarly half the ova produced by the female get the gene for red-eye colour and the remaining half the gene for brown. With two kinds of sperms and two kinds of ova, four kinds of zygotes are possible : (1) A sperm with red-eye gene uniting with an ovum with red-eye gene produces a zygote with two red-eye genes. This zygote will produce an individual with red eyes. (2) A sperm with red-eye gene uniting with an ovum carrying a brown-eye gene will produce a zygote with two genes, one for red-eye colour and one for brown. The red being dominant, the individual will have red eyes. (3) A sperm with brown-eye gene unites with an ovum carrying a red-eye gene. The result is the same as in the last case. (4) A sperm with brown-eye gene unites with an ovum carrying a brown-eye gene. The zygote will have two genes, both for brown-eye colour. Since the dominant gene is not present, the genes for brown-eye colour are able to manifest themselves and the individual is brown-eyed.

Note that with respect to the visible features there are two kinds of individuals. Those in the categories (1) , (2) and (3) above are red-eyed and those in category (4) are brown-eyed. This gives the proportions of the red-eyed and brown-eyed individuals as 3 : 1. With respect to the genetic constitution, there are three kinds of individuals. Those in category (1) have both genes in the pair for red-eye colour ; those in categories (2) and (3) have one member of the gene pair for red-eye colour and the other member for brown-eye colour ; those in category (4) have both members of the pair for brown-eye colour. The individuals of the three genetic constitutions are in the proportion of 1 : 2 : 1. The individuals of categories (2) and (3) look like those of category (1) because of the phenomenon of dominance (FIG. 18). The result of their breeding will, of course, be different. The characters of the offspring in the next generation depend not upon the characters of the parents but upon the genetic constitution of the gametes produced by the two parents and the manner in which the gametes unite to form the zygotes.

The above explanation fits the observed facts admirably. Compare also the behaviour of genes as stipulated by Mendel with the behaviour of chromosomes. There is alternation in the number of chromosomes—two sets in the body cells, one set in the gametes. The same is true of genes. This is one of the reasons for the conclusion that hereditary factors or genes are situated in the chromosomes.

The phenomenon of dominance is not universal. When a pure breeding, red-flowering plant of "four-o'clock" is hybridized or crossed with a white-flowering plant, all the plants in the first hybrid generation are pink. They resemble neither parent completely and are intermediate between the two. When a pink-flowering plant of this generation is crossed with another pink-flowering plant of the same generation, the results are interesting. Approximately 1/4 of the offspring are red-flowering, 1/2 pink-flowering and 1/4 white-flowering (FIG. 19). Compare these results with the inheritance of eye colour in the fruit fly. In the present case there is no dominance. As a result, there are as many visibly different types as there are genetic constitutions.

You should now be able to explain cases like these : when the parents differ in some character, the children may resemble only one of the two ; when the parents are unlike, the children may differ from both of them ; parents that are alike may produce some offspring like themselves and others unlike ; parents that are alike may produce children of three kinds, one kind like them and two kinds unlike them ; some children resemble parents, others grandparents ; individuals that look alike may produce children that are different.

Principles of Independent Assortment and Linkage

In the preceding examples a single pair of characters has been considered. Let us now see what happens if two pairs of characters are studied simultaneously. A female guinea pig, pure for black hair colour and short hair, is crossed with a male, pure for white hair colour and long hair. In the first generation all the individuals have black, short hair. Obviously blackness of the hair is dominant and whiteness recessive and short hair character is dominant over the long hair character. When female and male guinea pigs of this generation mate, they produce offspring of four kinds : (1) those with black short hair, like the grandmother, (2) those with white, long hair, like the grandfather, (3) those with black, long hair, a new combination or recombination of the two original characters not exhibited by the parents or grandparents, and (4) those with white, short hair, another recombination of the two original characters not exhibited by the parents or grandparents. The four kinds of individuals occur in the ratio of 9 : 1 : 3 : 3 (FIG. 20). The appearance of all these kinds of individuals and their proportions can be explained in the same manner as in the case of a single character pair. You should note that the two characters present in either parent in a particular combination need not always appear in the offspring in the same combination. They can separate and then form new combinations, i.e., they assort independently. This is Mendel's principle of independent assortment. It can be explained simply by supposing that the genes showing independent assortment are carried by different chromosomes.

While many characters are known to assort independently, there are others that do not. They have a tendency to remain linked together in the same combination in which they are present in the original ancestor. You can easily explain it by suggesting that the genes showing linkage are carried by one and the same chromosome and cannot, therefore, segregate. If linked genes are really carried by one chromosome, they should show linkage without exception. But the genes that show linkage, often do not show it in 100 per cent cases. This is explained by the fact that chromosomes occasionally break into parts and the parts then rejoin. During this rejoining, two chromosomes can exchange their parts leading to independent assortment of genes that were linked originally.

A great deal of research has suggested that genes are not only situated upon chromosomes but are arranged upon them in a regular order. Chromosomes of many organisms have been studied so thoroughly that their maps have been drawn showing the location of the various genes.

What has been said about the behaviour of chromosomes and genes in relation to inheritance is an oversimplified picture of the whole situation. The mechanism of inheritance is really very intricate and complicated. Characters are known to be governed not by one or two but several genes. On the other hand, although a gene may have a distinctly prominent effect on one particular character, its total effect may be much more widespread and may influence the action of many other genes. Genes cannot act in isolation; they interact with one another.

Importance of Genetics

The study of genetics has corrected many wrong ideas about heredity. Many people identify heredity with blood. "The blood of warriors is running in our veins" assert some with pride. Many think that the thoughts of the parents during mating or those of the mother during pregnancy influence the features and character of the baby to be born. Others invoke the help of magic, witchcraft, talismans, charms, mantras or prayer, drugs or other preparations to have the kind of child they desire. Even the little that you have read about genetics so far is enough to show the absurdity of all this.

Genetics has been applied very successfully to agriculture and animal husbandry. Many new varieties of plants and animals have been produced by careful selection and hybridization. The fact that characters existing separately in different individuals can combine and exist in one individual (independent assortment) is of great practical application. New varieties of plants and animals are being produced in which individuals combine in one the good qualities of two or more different varieties. These are better suited to human requirements than many natural varieties. Some geneticists feel that genetics can and should be applied to improve mankind. It is a difficult and delicate subject, raising many problems and controversies. Breeding human beings according to the wishes of the geneticist is not as simple as breeding peas and fruit flies. In spite of the many difficulties, however, the subject gives some hopeful indications. The contribution of genetics to the science of medicine is also very considerable.

The question concerning the relative importance of the roles of heredity and environment is intimately related to many social and individual problems. The manifestation of any particular character or the development of the individual as a whole is the result of interaction between the hereditary and environmental factors. Certain characters may be described as *predominantly* hereditary or genetic, and others as *predominantly* environmental. Between these two extremes are experienced all grades of variation in the relative importance of the two sets of factors. The relative importance of the roles of the two sets of factors varies also from character to character in the same organism. In no case, however, is it possible to ascertain the exact proportions of the two. The relationship between the two factors is so intimate and so complex that an exact answer is not possible.

Identical twins provide interesting material for the study of the problem of nature versus nurture. Ordinary twins and triplets etc. are simply brothers and sisters born together and show no greater similarity to one another than ordinary brothers and sisters do. They may be of the same sex or of different sexes. Such twins and triplets etc. are born as a result of the occasional fertilization of two or more ova at the same time. Identical twins, on the other hand, are distinguished by an amazing degree of likeness. They are of the same sex and resemble each other so closely in other respects that even parents may find it difficult to distinguish one from the other. Usually one zygote develops into one embryo. Occasionally, when the embryo is still very young consisting of a very few or only two cells, a split may divide it into two separate parts which develop into two separate embryos. Since the two are derived from a single zygote, they have exactly the same genetic constitution. This explains their extraordinary resemblance and makes them identical twins. Identical twins have sometimes been separated in infancy and brought up separately; yet they have shown remarkable resemblances, much greater than those between ordinary brothers and sisters or even ordinary twins. The conclusion is that the characters in which they resemble are primarily hereditary. The characteristics in which they show differences are primarily environmental.

If everything in the personality of an individual were due to heredity alone, identical twins would be exactly identical even if they were separated and brought up in different environments. They are certainly similar to an extraordinary degree, but they are not exactly identical. This means that heredity has an overwhelming influence, but it is not everything. On the other hand, if environment alone were responsible for the characters of an organism, ordinary twins brought up in the same environment should be as similar to each other as identical twins brought up together. Again, this is not so, even when the ordinary twins are of the same sex.

Are geniuses and idiots, scholars and dunces, social benefactors and criminals produced by the environment or by genetic factors? All that can be said is that genetic factors certainly determine many of the potentialities of individuals, but environment certainly plays an important role in the proper development or suppression of those potentialities.

In the life of any individual both heredity and environment are important. While the hereditary constitution of individuals cannot be altered, environmental conditions are amenable to modification and improvement. The hereditary potentialities of an individual need proper environment for their development. The extraordinary hereditary potentialities of a person that might make him a genius will not develop properly if he or she is not provided with suitable food, proper protection from unfavourable conditions of the weather, and proper education and training. Inadequate food can even bring about death although it may be a slow one ; so also exposure to inclement weather can kill him and all his hereditary potentialities will come to naught. Genetics thus puts the problem in its proper perspective. It enables us to think rationally about such social problems as the equality or inequality of man, proper distribution of economic and social amenities, provision for proper education, training and other opportunities suited to the potential capabilities of different individuals and other similar social questions.

Many people take pride in belonging to a so-called noble family. Others think that there are superior and inferior races. They even cite genetics in support of such views. This has been the cause of much strife and bitterness. Differences between one species and another, between one variety and another and between individual and individual have to be admitted. No two individuals are exactly alike. But the significance attached to these differences should be rational. Differences must not be confused with superiority and inferiority. Things that are different are not always necessarily superior or inferior to each other. The question of superiority or inferiority is difficult to decide in many cases. The criteria of superiority can vary from individual to individual, from country to country, and from age to age. Standards vary. What is considered to be a matter of pride by one group of people may be regarded as a matter of disgrace by others. Those who take pride in racial superiority forget that there have been dark and bright periods in the history of so many races. Those who were at the height of their glory yesterday may be a non-entity today. Those who are downtrodden today, may be the envy of every one tomorrow. But those who have blind faith in their own eternal superiority and in the eternal superiority of things and beliefs dear to them are not amenable to reason. The study of genetics can help us to develop a scientific attitude towards such problems.

Part II

THE EVOLUTION OF LIVING BEINGS

CHAPTER NINE

The Meaning of Organic Evolution

The Historical Approach

A magician waves his magic wand and there appears instantaneously before your eyes, as if from nowhere, a mighty tree where there was not a trace of green to be seen. You are bewildered. But if you see the seed germinate, the first root and the first shoot come out, elongate bit by bit, the leaves unfold one by one, the plant growing from seedling to sapling, from sapling to a young tree, and then see it grow strong and mighty day by day, you find nothing to bewilder you. You seem to understand everything. Why this difference? You were amazed in the first case because you saw only the final stage of the tree and you were ignorant of the events preceding its sudden appearance. In the latter case you feel at home with the tree because you know the continuity of events, that is, you know the history.

Can you imagine a river with its water in a stationary condition? A continuous flow of water is the very essence of the life of the river. If the water stops moving, the river ceases to be a river. Can you think of seeing what a river is simply by standing on the bank of the river and gazing at the water before you? You are seeing only a fraction of the whole. To visualize the river in its entirety, you have to think of a stretch of water hundreds of miles in length, now trickling, now swelling into a ferocious torrent, here breaking into rapids and falls, there moving slowly and quietly, starting from the snows of some mountain, descending down the rocks, flowing into deep gorges, along valleys, through dense forests, meandering over meadows and plains, washing and cleaning cities and hamlets, and eventually meeting and becoming one with the sea. And, this is not all. Has this river always been there exactly as you see it today, since its very beginning? It had its birth, its infancy, its childhood, its adolescence, its youth and then it attained its present impressive proportions. Again, if you go to the bank of the same river on two consecutive days, do you see the same river, the same water ? A river is not the same from day to day. It is not the same even for two consecutive minutes or seconds. Its water is constantly changing. Now compare this picture of the river with the first one you saw by simply standing on the bank of the river at a particular place, at a particular time. Is the second picture not more complete ? Is it not also more fascinating ? The first is a miserable caricature of a fraction of the whole which is so grand, so majestic. If you desire to enjoy this grandeur and charm of things, and to understand them in their entirety, you have to see them in their proper perspective, in their natural setting, and appreciate their continuity in structure, in space and in time. History is one of those instruments that helps us to see things in their true perspective and appreciate their continuity in time. And history is all-pervading, all-embracing, because everything has its history.

To appreciate the continuity of events in this universe, the series of changes through which the earth has passed, the succession of stages in the development of living organisms, the gradual unfolding of the dramatic story of society, in a word to know their history, is to understand the universe, the earth, the world of life, the human society.

Just as you cannot enjoy and understand a good novel by reading its last chapter, or a beautiful cinematographic story by seeing the last reel only, so also you cannot appreciate and enjoy the study of living organisms unless you know their historical continuity.

History of the Living World

The variety of form seen in plants and animals around us is almost unlimited. You have had a faint glimpse of this variety earlier. As you know, biologists have already discovered more than a million different species of plants and animals. You also know that one species of animals or plants may have dozens or hundreds of varieties. The great variety in nature has stimulated the biologists to ask questions such as : How has this wonderful variety in the members of the living world come about ? Has this variety been always there since the very beginning of life or has it changed with the passage of time ? Did all the different kinds of animals and plants come into existence independently, each one separately, or does there exist any relationship among organisms apparently so different from one another?

The great variety of the living organisms as we see it today has not been there from the very beginning of our earth nor has it come about suddenly. When the earth first came into existence it had no life upon it. In fact it was too hot and unfit for the existence of living organisms. Conditions improved later and the substance that constitutes the bodies of all living organisms, namely, protoplasm, made its first appearance in the form of very simple living organisms. It is impossible to say exactly how long ago this happened. It is certain, however, that this happened hundreds of millions of years ago. As time passed and the first simple living beings reproduced generation after generation, there appeared, among their offspring, organisms somewhat different from the original form. Gradually there appeared, among animals, organisms like the amoeba, various kinds of worms and insects. Among plants arose new forms resembling algae, bacteria, moulds and mosses. When these new forms propagated themselves there appeared among their offspring still newer forms. Among animals there appeared those with a vertebral column like fishes, frogs, reptiles etc. Among plants, forms like lycopods and ferns came into existence. Later, there appeared among the animals, birds and mammals. The most recent development in the latter group of animals is the emergence of apes and man. Among the plants evolution produced new forms that bore flowers, fruits and seeds. The various kinds of flowering plants, that constitute the dominant vegetation of today and the mammals including apes and man, represent the latest stage of the story that began with the first appearance of living matter on the earth (FIG. 21).

The Theory of Organic Evolution

The history of the living organisms, briefly outlined above, is referred to as organic evolution. The word evolution means unfolding or unrolling. It is ordinarily used in the sense of gradual and orderly change leading to the development of one form from another, usually complex forms from simple ones. It may refer to such change in the objects found in the inanimate world or it may refer to the world of life. One may talk of the evolution of matter from its simple form to the most complex. One may speak of the evolution of stars, of the earth and of the universe or of the evolution of life and living beings. Organic evolution refers to the evolution of living organisms. The essence of the principle of evolution is the development of new forms from those already in existence in gradual stages, step by step. An important conclusion based upon evolutionary principle is that all living organisms are related to one another by common ancestry. This principle is in contrast to that of special creation which suggests that each kind of organism was created separately and independently and that, therefore, there is no continuity or relationship whatsoever among the different kinds of living beings. But it is impossible for the supporters of this principle to ignore the fact of evolution completely. They can assert that the first human couple did not evolve from pre-existing animals but was specially and independently created. But then, how can they explain the descent of such different kinds of human beings as the Caucasians, the Negroids, the Mongoloids and the Australoids from the same single pair of man and woman. Obviously evolution has to be accepted to explain variation within a species. Those who accept the principle of organic evolution, simply extend its application from the narrow confines of species to the entire living world.

The study of organic evolution, or the gradual development of the living organisms from the earliest times till today, aims at answering questions some of which have been stated earlier. The historical approach to the world of life has brought about a revolution in many branches of knowledge. As a result, our mode of thinking and our attitude towards many academic and social problems have been modified. It has enabled man to view his own species in correct perspective. The concept of organic evolution has enabled us to understand ourselves in relation to other beings and in relation to the non-living world. It is of far-reaching significance.

CHAPTER TEN

Is It Possible?

According to the theory of organic evolution the flowering plants evolved or originated from the simpler, non-flowering plants which themselves evolved from others much simpler. Man and apes descended as offspring of primitive mammals which, in turn, had their origin from reptiles. The reptiles themselves came from other simpler and more primitive animals. Is this possible? Can fishes be the ancestors of reptiles and reptiles the ancestors of primitive mammals? Can the primitive mammals evolve into apes and man? Can plants and animals already in existence give rise to new kinds of plants and animals? Is this possible?

A Dutch botanist, Hugo de Vries, studied a plant called evening primrose. He cultivated it in large numbers. He noted that occasionally there appeared in his experimental plots some individuals which were different from the normal plants in some character to such an extent that they could be easily spotted out as distinct forms. When seeds from these new forms were sown they produced plants all of which were like the new individual. In this way new forms were detected as arising from the old types and they were established as new strains, races or varieties by further propagation. One individual appeared with unusually large leaves and flowers etc. Its origin was described as spontaneous, i.e. without a known cause. It produced its own type in future generations and established a new "gigas" (giant) strain. Another individual appearing naturally in a similar manner, was only about 1/5th of the normal plants in height. It bred true and established a new dwarf race. De Vries gave the term "mutation" to these variations that appeared spontaneously, which were quite distinct from other forms and were also hereditary. The phenomenon of mutation has been observed in many cultivated plants. Many of the new varieties of ornamental and other plants and animals have come into existence in this manner.

A farmer of New England, living in the 18th Century had a flock of ordinary sheep. In this flock was born a male lamb with extremely short, bowed legs. The farmer took care of the lamb and bred from it. This gave rise to a new variety of sheep, the Ancon breed, with legs so short that the sheep could not jump over an ordinary stone wall. This was obviously an advantage to the farmer. This breed became extinct afterwards but the same mutation appeared again later in the flock of a Norwegian farmer. A new strain of short-legged sheep has therefore been bred again. (FIG. 20 a).

The white races of many domesticated animals are known to have evolved from ordinary pigmented types. Hornless varieties of cattle have evolved from ordinary types with horns. The fruit-fly, *Drosophila melanogaster*, has been a favourite object of study with the geneticists. In experiments with this little fly, a very large number of new strains have been observed to evolve from the ordinary type by mutation. For instance, in a normal. true breeding red-eyed strain there appeared a single individual with white eyes and established a new race of white-eyed fruit-flies. Numerous strains have been evolved showing other variations in the character of eyes. Some have bar-shaped eyes. others kidney-shaped, still others with other shapes, and, sometimes individuals are born with no eyes at all. Numerous new races of fruit-flies with new wing characters have been evolved from those with normal wings. New races with curly wings or vestigial wings or races with no wings at all have originated in this manner. Flies with ebony coloured bodies have evolved from those with normal gray bodies. (FIG. 20 b-d).

The appearance of new varieties from those already in existence has been observed in many different kinds of plants and animals. One more example will be cited here because this might appear to you more convincing. All of you know the ass, the horse and the mule. But some of you may not know the relationship among these three animals. When the male ass and the female ass mate, they produce baby asses. When the male horse and the female horse mate, they produce baby horses. What do male and female mules produce when they mate? "Mules, of course!" some of you might exclaim impatiently and wonder why the question should at all be asked.

The answer seems obvious to those who do not know. The fact is that the male and female mules do not produce baby mules. In fact, they produce no babies of any kind. They are sterile. "Impossible", you assert and ask, "How do we then get mules?" A mule's father is not a he-mule, nor his mother a she-mule. A mule's father is an ass and his mother a mare or a female horse. When a male ass and a female horse mate, their offspring is neither a baby ass nor a baby horse. It is something distinctly different. It is a mule. It is a very useful animal, having some of the good qualities of both the ass and the horse. A new kind of animal, the mule, arises or evolves, from two animals already in existence by hybridization. Many new and useful kinds of animals have been evolved by animal breeders by hybridization, combining the good qualities of different individuals into one. Similarly plant breeders have produced, by hybridization of pre-existing plants, many new and better varieties of crop plants, vegetables, fruit trees and ornamental plants.

The examples given above are all based on actual observation and controlled experimentation. They are quite adequate to demonstrate the possibility of organisms giving birth to new kinds. Many of these new kinds are capable of reproducing their own type establishing new races and varieties that contribute to evolution. You may point out that while it is easy to appreciate red-eyed fruit-flies evolving into white-eyed or the ass and the horse producing the mule, it is not so easy when we come to the question of reptiles evolving into birds and primitive mammals, or primitive mammals evolving into apes and human beings. True, but please note that the difference lies only in the degree of change. The world of life has a long, long history. When you talk about this history you speak not in terms of a few years, decades or centuries, you speak in terms of millions of years. And when you keep this fact in mind, the evolution of the most highly evolved organisms from the most primitive ones becomes fundamentally almost as simple to understand as that of the white-eyed fruit-fly or the mule.

Mutations have not only been observed in plants and animals but have also been produced artificially and experimentally by geneticists. This is even more significant. Plant and animal breeders today are producing new forms of plants and animals from those already existing in such numbers that the matter is now considered commonplace. It no longer requires theoretical arguments to convince any one of the possibility of this phenomenon. The stage of controversy about the possibility and occurrence of evolution is long past. Biologists are no longer merely describing evolution. They are themselves guiding the evolution of some of those plants and animals in which they are interested, in their own laboratories and experimental fields. Some of them even think of guiding the future evolution of man.

CHAPTER ELEVEN

Evidences of Organic Evolution—Part 1

Sources of Evidence

The theory that organic evolution has actually occurred in the past or that plants and animals have changed during the course of the ages is based upon evidence derived from several sources. The more important and direct source of this evidence is the history of the living beings as studied from the remains of living beings of the past. This is what we should expect. As explained earlier, the principle of organic evolution is simply a scientific interpretation of the historical sequence in which the various living beings appeared on this earth and lived and evolved further or became extinct after some time. There are several other sources of evidence but they are not as direct as the historical source.

To understand the continuous succession of one form of life after another during the past, it is necessary to study the subject in the same way as historians study history. Upto a certain period in the past, history can be studied from written records left by ancient people. But this method does not take us very far back. Very soon it is realized that in the earlier stages of human history there was no reading and writing. Conclusions about the conditions prevailing in those times are therefore based upon the remains of things that were produced and used by the people of those times. These remains include the various articles and implements of everyday use. These are usually found buried under the earth in places where there were originally human habitations. Entire villages and towns with their houses and streets have in some places been discovered buried under the earth. By uncovering these buried remains of the past, archaeologists have learnt a great deal about ancient human cultures. Many animals and plants of the past also got buried under the earth at the time they existed. The remains of living organisms of the past or their traces preserved in various ways are called fossils. The study of fossils (Palaeontology) reveals the history of the world of life in a remarkable manner.

Fossil Evidence of Organic Evolution

It is common knowledge that food keeps longer without putrefaction in a frigidaire or in cold storage. Entire bodies of the mammoth, an elephant-like animal now extinct, have been discovered in the frozen soil of Siberia. It is estimated that they were in this natural cold storage for about 20,000 years. These bodies became buried complete with flesh which was still red when the fossils were discovered. Similarly animal bodies soaked in oil have been found in oil-containing rocks. Usually only the hard parts in the bodies are preserved although some times an indication of the outline of the body may also be obtained. Bodies or parts of bodies may be deposited at the bottom of lakes and seas and then covered with sediment. Fossils may also be formed by burial under sand or volcanic ashes.

The presence of hard parts in the body such as bones in animals and woody tissues in plants is a factor that favours their preservation as fossils. Another important factor in fossil formation is the immediate burial of the bodies. In many cases preservation is accompanied by chemical change and may be described as petrifaction. Bones are usually preserved by deposition of mineral matter in the pores. When woody tissues are preserved, there may be replacement of their chemical substances by mineral matter. The replacement may occur particle by particle in such a delicate manner that even microscopic structures may be preserved. Carbonized fossils are produced when organic matter of the bodies is changed in such a way that only carbon is left. Coal is an example of this mode of fossilization. Sometimes an organism becomes embedded in rock and then its body is dissolved away. A cavity is left in the rocks and acts as a mould. The mould is later filled with material and produces a cast showing the shape of the original organism. Casts of even soft bodied animals like jelly fishes and worms have been preserved in this manner. The bodies of some organisms or their parts have left their impressions on rocks.

Even the footprints of some animals that lived many millions of years ago have been preserved.

Fossils found embedded in sedimentary rocks are of special importance as evidence of organic evolution. To appreciate this evidence it is necessary to understand how sedimentary rocks are formed.

Rivers flowing down the mountains in the form of torrential streams, bring down with them huge rocks and boulders which break into smaller and smaller pieces as they approach the foot of the hills. In the plains the rivers move slowly and leisurely and the heavier pieces of stone settle down. The finer and lighter particles remain suspended in water in the form of sand grains. The water that flows into rivers carries with it large quantities of fine particles of sand and earth. All these are carried to the lake or sea into which the river falls. Here, the suspended particles gradually sink downwards and are finally deposited at the bottom of the sea. After a flood, a layer of mud can be seen deposited on the river banks that had become flooded. Similar layers are being deposited continually at the bottom of seas and lakes into which rivers are always bringing a good deal of matter. The action of wind, rain etc. erodes the rocks and soil. The eroded soil is removed by rain water and small streams to the rivers which take the material to the sea. Streams and rivers are also eroding their own banks and removing the soil to the sea. The material brought from various sources is deposited as sediment on the floor of the sea in layers. The layers are laid down one above the other. During the course of ages the lower layers, under the weight of the upper ones, and the upper layers under pressure of overlying water, become compressed and gradually hardened into stony rocks.

If the layers deposited under water are not disturbed and remain in the sequence in which they were laid down one above the other, it is obvious that the lowest layers will be the oldest in age. The subsequent layers will be successively younger and younger. The layers at the top will be the youngest or the most recent.

As the streams and rivers flow into the seas and deposit layer upon layer of sediment of mud and silt, they also carry with them the bodies of animals and plants that happen to fall into them for various reasons. These bodies are deposited at the bottom of the sea. The bodies of plants and animals living in the sea are also deposited on the sea floor. All these become covered by layers of sediment. As layers of sediment harden into layers of rocks, the remains of animal and plant bodies become embedded and preserved between them. Any particular layer of sediment or rock will naturally contain, embedded in it, the fossils of animals and plants of the time at which the layer was deposited. In any bed of rocks, in which the original sequence has not been altered, the lowest rocks will be the oldest in age and will contain fossils of animals and plants of the earliest period. The successively higher layers, relatively younger in age, will contain fossils of late periods. The uppermost layers will be the youngest in age and will contain fossils of animals and plants that came last of all. Thus, if the rock layers formed under water, and known as the aqueous or stratified or sedimentary rocks, could be studied together with their fossils in the sequence in which they were originally deposited, they will give us some insight into the historical sequence in which the different kinds of animals and plants appeared on the earth. This study will also reveal the sequence of changes that the living beings underwent in the past.

The earth is subject to various movements, some so slow as to be imperceptible, others violent like a severe earthquake. In the past, sometimes these movements were of such magnitude that they led to the separation of huge land masses or entire continents or brought together land masses that were apart. As a result of such movements, beds of some ancient seas were gradually pushed up to form mountains. The fossil-containing rocks that were formed under the sea can, therefore, now be seen on dry land and can be studied easily. The sequence has been upset in many places but, in others, the rocks have retained the original arrangement with very little modification. It is these rocks that are specially helpful in our study of the history of the world of life. Even when the original arrangement has been disturbed, geologists can often guess what it was.

Geologists and biologists have already unearthed a good deal of the history of our earth and living beings on the basis of rocks and fossils. Their findings support the theory of organic evolution. The historical sequence of the different kinds of living beings as discovered from the study of fossils agree with that suggested by the evolutionary theory.

Fossil Evidence—The Historical Sequence

Sedimentary rocks occur in layers or strata arranged in the order of their age. The various layers of sedimentary rocks are characterized by the occurrence of certain distinctive types of fossils. This is so characteristic that palaeontologists often identify the strata by the fossils contained in them. There are various methods of calculating the age of the rocks containing fossils. One of them is based upon the property of uranium of disintegrating into lead at a definite rate which is not influenced by environmental conditions. When a piece of rock contains uranium and lead occurring together in the form of a small nodule, it is concluded that the lead has been produced from uranium. If you divide the weight of lead in the nodule by the weight of uranium and multiply it by 7400, you would get the age of rock in millions of years.

For describing the history of fossils, the entire age of the sedimentary rocks is divided into eras which are subdivided into periods which in turn are divided into epochs. These are shown in the accompanying chart. (FIG. 21). You can ignore the technical names of periods or epochs and note only the broad divisions into eras. Read the chart from bottom to top to follow the sequence of rocks the oldest of which are found at the bottom and the youngest on top. Study the chart carefully and note the sequence in which the fossils of various plants and animals appear. Remember also that the chart presents only facts actually observed and that it is not based upon any theory or hypothesis. The facts shown in the chart are facts; they have to be accepted and have been accepted even by those who may not accept the principle of evolution.

The entire history of living beings shown in the chart covers 2000 million years. It has been divided into five major eras. The first or the oldest era is known as Archaeozoic or the era of primitive life. It began 2000 million years ago. The second era is Proterozoic or that of early life. These two eras together cover a period of about 1460 million years, nearly 73 per cent of the entire period shown in the chart. The third era, the Paleozoic or the era of ancient life, began 540 million years ago and lasted upto 200 million years ago, that is, for 340 million years. The fourth era, the Mesozoic or the era of medieval life, began 200 million years ago. It extended upto 60 million years ago, covering a period of 140 million years. The fifth and the last era is known as the Cenozoic or the era of modern life. It began 60 million years ago and extends till the present times. The era of modern life, that is of modern flowering plants and modern mammals covers only 60 million years out of a total of 2000 million years which is only 3 per cent of the entire fossil record.

It must be noted that each and every organism of any period could not have been preserved as a fossil. Only a very small fraction of organisms of any period may be expected to become fossilized. And then, only a very small fraction of all the fossils that occur in rocks can be unearthed and studied by man. Therefore, even a complete list of known fossils cannot give a complete picture of the life of the past. Fossil record is bound to be an incomplete record of past life. But it is the only record. In spite of its limitations, however, it has given us a glimpse into the past. There is little likelihood of the record misleading us if its limitations are kept in view and conclusions drawn critically. The following is a brief sketch of the fossil record.

The fossil record of the first two eras, the Archaeozoic and Proterozoic is very scanty in view of their vast extent in time. In the rocks of the Proterozoic era have been found fossils of simple organisms like the algae, the unicellular animals and the sponges. The highest form of animal life in this era was probably worm-like as suggested by fossil trails and burrows.

The early Paleozoic era exhibits a sudden abundance of fossils. Fossils representing most of the major groups of invertebrate animals occur in the very first period of the era. 60 per cent of the fossils of the age belong to trilobites which must have dominated the scene. The second period of this era is noteworthy for the fossils of primitive fishes. There is yet no trace of land plants or land animals. The ferns, seed-bearing plants, flowering plants, reptiles, birds and mammals including man are all conspicuous by their absence. The Middle Paleozoic period shows fossils of the first fernlike land plants in its first period and an abundance of seed bearing (non-flowering) plants in its second period. This period constitutes a landmark in animal history because it contains the earliest fossils of the first land vertebrates, the amphibians. This is a group represented today by animals like frogs and salamanders. The Late Paleozoic, also known as Carboniferous period, is characterized by the great coal beds formed by fern-like trees. Fossils of seed-bearing plants (gymnosperms) occur but there is no trace yet of flowering plants. The Late Paleozoic period is also called the Age of Amphibians which was now more widespread than in the earlier age. The land-mark of this age, however, is the first appearance of reptiles which became the dominant animals in the next era, the Mesozoic.

The Early Mesozoic era is called the Age of Cycads because they were the most characteristic plants of the age. There is no indication of flowering plants yet. From the point of view of animal fossils the Mesozoic era was the Age of Reptiles. Some of them were the largest animals of all time. The longest, a dinosaur, measured nearly 90 feet in length. The Early Mesozoic is also the age in which fossils of primitive birds and primitive mammals are seen for the first time. The earliest known bird, *Archaeopteryx*, found in this age will be described later. The Late Mesozoic age is a landmark in the history of plants because fossils of flowering plants are seen in this age for the first time.

The Cenozoic era is the modern era. Modern plants and animals, viz. flowering plants, birds and mammals had already appeared in the preceding age; they now dominate the earth. The Early Cenozoic age shows series of fossils through the different strata of rocks leading step by step to modern mammals such as the horse, the camel, the elephants, monkeys and anthropoid apes etc. No human fossils have been discovered in this age. Existence of man-like beings in the last period of this age is inferred, however, from the presence of worked flints. The Late Cenozoic is the Age of Man. The first actual fossils (apart from worked flints) that suggest a direction leading towards man have been discovered in the rocks of this age. Fossils of the "Java ape-man" (*Pithecanthropus erectus*) and the "Peking man" (*Sinanthropus pekingensis*) have been discovered in rocks less than a million years old. The Java ape-man, as the name suggests, had some features of apes and some of man. Fossils of the Neanderthal man (*Homo neanderthalensis*) occur in rocks not more than 200,000 years in age. The fossils of the modern man (*Homo sapiens*) occur in younger rocks, about 150,000 years or less in age. You will read about human evolution in detail later in this book. Some authors think that the last 25,000 years of the Cenozoic Era should be classified as a separate era and named the Psychozoic Era, the era of intellect.

The above account of the historical sequence of fossil plants and animals, although very brief, is adequate to enable you to appreciate the evolutionary interpretation. Note how life began with simple forms in the earliest age, how new forms appeared in succession one after another, leading in general, from simpler to more complex forms, how each age was dominated by certain kinds of plants and animals which become less important or extinct in later ages, how the sequence of the various forms of life has culminated in flowering plants on the one hand and mammals on the other, and finally, how man, the most modern mammal, may be regarded as the highest form of life known so far. It is possible that future discoveries of more fossils may modify the above account to some extent. This will however not contradict evolution unless future discoveries reveal a sequence of organisms fundamentally different from that described here.

Fossil Evidence—A Closer Study

The preceding account has dealt with the major groups of plants and animals. In order to be able to appreciate better how new species may have succeeded one after another, starting from the earlier ones, step by step, it is necessary to undertake a closer study of specific examples. Among the animals whose fossil history is better known is the modern horse. A series of fossils following one another closely has been discovered from the various strata of rocks of the Cenozoic era. Study (FIG. 22), showing fossils of the horses of various periods of this era.

The fossils of the earliest horse-like animal (*Eohippus*) occur in the first period (*Eocene*) of the Cenozoic era. Note the series from the earliest period to the Recent period and see how the successive forms, as seen in the first column of the figure, show a gradual, step-by-step, change in the overall size of the animals leading ultimately to the modern horse (*Equus*).

The succession of the series of the various steps leading from the earliest to the latest becomes even more impressive when we look at the skeleton in greater detail. The second, third and the fourth columns in FIGURE 22, show the fossil bones of the forefoot, the hindfoot and the teeth of the horses belonging to different periods. Note the gradual change in each column. Let us study the forefoot. See the forefoot of the earliest horse at the bottom in the second column. It has four toes and a splint bone (on the left). It is essentially like the foot of many animals with the usual five toes. The little splint bone represents the first toe which has been greatly reduced. The third or the middle toe is larger than others. All the four toes touch the ground and help in walking and supporting the body. Compare this with the fossils of the next period. The reduced first toe is now completely absent. The fifth toe is represented by a small splint bone (on the right). It seems to be following the course of the first toe. Of the remaining three toes, the middle or third is much larger than the second and fourth toes. All the three toes touch the ground. Now compare this with the forefoot of the horse of the next period which has three toes, viz. second, third and fourth, like the preceding horse. The second and fourth have become much shorter, however. They have become so short that they no longer touch the ground; they dangle in the air. They are following the destiny of the first and the fifth toes. All the weight of the body is now supported by the middle toe which alone touches the ground. Its relative size is much larger now and the forefoot as a whole is larger in this horse than in the earlier one. Follow this further through the remaining forms, compare it with the modern horse and note the continued reduction of the second and fourth toes to mere splints. The extraordinary enlargement of the middle toe is noteworthy. The hoof of the horse is simply the nail on this toe. The modern horse thus shows the culmination of tendencies that first appeared in the forefoot of the earliest horse. Now follow similarly the series of changes in the hind foot and the teeth.

You have studied the wonderful series of stages in the fossil history of the horse. Its overall size, its forefeet and hind feet, its skull, jaws and teeth etc. all lead, by gradual stages, from the earliest form to the most modern. Is there any meaning in this sequence of fossils? Biologists answer this question in the affirmative, and the meaning they read in the sequence of fossils is embodied in the principle of organic evolution.

Fossil Evidence—The Connecting Links

If the variety in the world of life is the result of the evolution of new forms from other earlier forms by gradual change, one would expect the occurrence of forms intermediate between the earlier and those which have evolved from it.. If birds and mammals have evolved from reptiles, are there any animals that may be regarded as partly reptile and partly bird or as partly reptile and partly mammal? If man has evolved from other animals, are there any connecting links between man and his ancestors?

The fossils of the earliest bird known so far, the *Archaeopteryx*, have been recorded from the Early Mesozoic period. It has been called a reptile-bird and may be treated as a connecting link between the reptiles and birds. Reptiles have no feathers while birds have feathers. Reptiles have fore-limbs and hind limbs with claws although these have disappeared in some of them, e.g. in snakes. Birds have hind limbs but the fore-limbs have been substituted by the wings used for flight. Reptiles have a tail with a bony skeleton inside. Birds have no such tail although they have a few feathers at the end of the body which are called tail feathers. Reptiles have teeth while birds have no teeth. The reptile-bird, *Archaeopteryx*, had a tail with a bony skeleton and had teeth. In these characters it resembled reptiles. It had feathers and wings, the characteristic features of birds. Its wings deserve special attention. They are really half claws and half wings. The claw-like parts consist of three fingers, attached to the winglike part. It is as if a reptile has been caught midway in the process of evolving into a bird. It is as if the fore-limb of a reptile has been caught midway in the process of evolving into the wing of a bird. (FIG. 23.)

Connecting links like *Archaeopteryx* were not known commonly when the theory of evolution was first definitely formulated. Those who were not willing to accept the theory demanded the production of connecting links. If the demand could not be fulfilled, they would reject the theory as unsatisfactory. Today, connecting links are known in plenty both in the plant kingdom and in the animal kingdom. The entire series of fossil horses described earlier is a series of connecting links. Scientists have been in quest of the so-called missing links between man and his ancestors. The Java ape-man, the Peking man and the Neanderthal man have been mentioned earlier. It is hoped that future studies will result in the discovery of more missing links and throw more light on the evolutionary history of man.

CHAPTER TWELVE

Evidences of Organic Evolution—Part II

Classification as Evidence of Evolution

Resemblances and differences among organisms provide the basis for classification. Similar individuals are grouped into species, similar species into genera, similar genera into families and so on. The basis of resemblances in essential characters is common descent or common ancestry. Resemblances can be produced in unrelated organisms by common environment but these can very often be distinguished from the more fundamental ones.

If groups of plants and animals such as species or genera differed from one another by clear-cut, well-defined characters, classification would be easy. But it is not always so. Organisms are often discovered displaying characters intermediate between other groups which were formerly considered as distinct and well-defined. These connecting links create a problem for taxonomists. You know an example from fossils, that of the reptile-bird. Should the reptile-bird be classified with reptiles or with birds? Or, should it form a separate category by itself? Or, should reptiles, birds and reptile-birds all constitute one group? Experts often differ in their answer to such questions.

See the figure showing a series of fossil snails of different forms. (FIG. 24). When only the forms shown at the extremes were known, they were treated as separate species. More forms were discovered later and these were intermediate. The question arose: Is each one of these forms a separate species, or, are all the forms merely varieties of a single species? This raises the question, "What is the definition of species?" You will be surprised to learn that, as yet, no definition of the term species is available that may be acceptable to all biologists. All these difficulties of the taxonomists furnish evidence in favour of the theory of organic evolution. If evolution is a fact, continuity from one form to another is to be expected. When some of the intermediate stages become extinct, groups are clear-cut. When they continue to exist, they form connecting links and make the work of classification difficult.

Comparative Anatomy

The comparative study revealing resemblances and differences between organisms is even more significant when you study internal structure. It reveals a common plan of structure in related organisms even when they may have superficial differences. Consider for example a few vertebrates. The claws of reptiles, the wings of birds, the wings of bats, the limbs of the horse and the limbs of man are apparently very different from one another. Comparative anatomy, however, reveals that they are all built on the same plan, each showing some modification of the common fundamental plan which has produced its characteristic form. How the foot of the horse with only one toe has been derived from the original plan, step-by-step, is already known to you. Similarly, different trends of evolution have produced other modifications all derived from the fundamental original plan. Look at FIG. 25 showing the skeletons of the gorilla and man. Here a common plan based upon common ancestry is evident. The two have the same number of bones. Every bone in one is represented in the other. They differ only in size and proportions.

Vestigial Organs

Comparative study of structure, whether external or internal, brings to light an interesting phenomenon, the phenomenon of vestigial organs. Vestigial organs are organs present in a reduced form and are functionless. Men and some apes have no visible tail. Other apes considered as their relatives have tails. Gorilla and man are tailless but look at their skeletons, once again, carefully. You will find the tail bones there in both of them. They are of course reduced and, in the living individuals, these little bony tails are concealed under the skin. What does this indicate? The most probable meaning is that this is a proof of the evolution of man and of the tailless apes from other ape-like ancestors that possessed complete tails. During the course of evolution, side-by-side with other changes, the tail has been reduced to a vestige. There have been rare cases of human babies born with an external, visible tail. Many vestigial organs are known in a great variety of organisms. The human body itself contains a considerable number of them. The only satisfactory explanation for their occurrence is that based on the theory of organic evolution.

Comparative Embryology

Visit a pond in the rainy season. Watch the little fish-like animals, called "tadpoles", swimming actively in water. Like fishes, they have tails and fins for swimming and have no hands and legs. Like fishes, they have no lungs and cannot live on land. They breathe with gills. Are they really fishes? Look at the frogs on the land about you. They have hands and legs and lungs. They have no tails and no gills. If you are lucky or a keen searcher, you may also observe little baby frogs jumping about with their little hands and legs and also carrying a little tail. If you could watch constantly the little fish-like animals in water for a sufficiently long period, you would see something wonderful. You would watch the little fish-like tadpoles gradually changing into the baby frogs with the little tail, and then you will see the latter losing the tail altogether and growing into adults. (FIG. 26). Why is a frog not frog-like from the very beginning? Why is it fish-like at first, a little baby frog still carrying a tail later, and finally a tailless adult. The only satisfactory explanation is that furnished by the theory of evolution. The course of the development of an individual frog suggests the history of the race of frogs as a whole, that most probably frogs evolved from fish-like ancestors.

Now look at the illustration of the embryos of some more vertebrates in FIGURE 27. They are arranged in three rows depicting three stages of development. The top row shows the earliest stage, the middle row an intermediate stage and the bottom row the last stage. The first four embryos represent lower vertebrates: the fish, the salamander, the tortoise and the chick. The remaining four are mammals: the pig, the calf, the rabbit and man. In the third row they are all sufficiently distinct from one another. But study the first row. At this early stage all of them are so alike that you cannot say which is which. The human embryo at this stage is not very different from that of the fish or chick or rabbit. The young embryos of all mammals have gill clefts although these animals breathe by lungs and have no gills. Examine the second row now. The fish and the salamander are more like each other and different from the rest. So are the tortoise and the chick. The pig, the calf, the rabbit and man are still very similar. Note the presence of the tail in all embryos including that of man at this stage. In man the tail usually disappears later as happens more or less in the frog. (Remember what you have read about vestigial organs). Again, organic evolution provides the only satisfactory interpretation. Their similarity at the earliest stage suggests that all animals included here have descended from common ancestors and are related. The second and third rows suggest that fish and salamander are more closely related to each other than to any other animal included here. Similarly the four mammals, the pig, the calf, the rabbit and man are more closely related to one another than any of them is to any of the remaining four animals.

Comparative embryology shows that the life history of an individual presents in an abbreviated form the evolutionary history of its race as a whole.

Selection and Breeding

Man has cultivated plants and domesticated animals for a long time. Many of these plants and animals are no longer found in nature in the wild state. But man certainly could not have created these varieties out of nothing. Most probably they evolved after the cultivation of selected wild plants and the domestication of selected wild animals. In the earlier stage this evolution was aided by man by simply selecting the best individuals in every generation for further propagation. Later, man began the hybridization of individuals possessing desirable qualities. Several examples have already been cited, such as the evolution of new varieties of the evening primrose under cultivation, of Ancon sheep with short legs under domestication, and the production of the mule as a result of hybridization. Selection and breeding have played a very important role in the evolution of new varieties by man under experimental conditions. Man has evolved experimentally new varieties and new species of living beings that did not exist in nature before. From his own point of view many of these new forms are better than the old ones in one way or other.

Other Sources of Evidence

In addition to the various sources of the evidence of evolution outlined here, there are other branches of biology that suggest organic evolution. No account of these sources of evidence is presented here because all that has already been said is quite adequate to convince any one of the soundness of the principle of evolution.

CHAPTER THIRTEEN

Evolution of the Theory of Evolution

The Early Period

In the preceding chapters we have studied the evidences in support of organic evolution. Evolution is now accepted as an established, incontrovertible fact by all biologists.

Many attempts have been made to explain how evolution occurs, how various causes bring about evolution. This is a field in which some controversy still exists although it has been reduced to a minimum in recent years. The various attempts to explain the mechanism of evolution have produced several theories of evolution. The present state of knowledge enables us to discard some and reconcile others.

The principle of evolution is not a very recent or new idea. Its history can be traced back to the age before Christ although the earlier ideas were vague. You must have heard Aristotle's name. He was a great philosopher and one of the founders of biology who lived from 384 B.C. to 322 B.C. He may be considered one of the founders of the principle of evolution because he emphasized the idea of gradual change from simple and imperfect to more complex and perfect. A religious leader, living in the fourth and fifth Centuries A.D. interpreted certain passages in the Bible as suggesting evolution. Buffon the great naturalist of the eighteenth Century believed in the ability of species to change.

The nineteenth Century witnessed a real growth of the evolutionary principle which now began to develop more and more along scientific lines. A considerable number of thinkers of this century expressed their views on the subject. We shall consider here briefly the contributions of four of them, viz. Lamarck, Darwin, Weismann and De Vries.

Lamarck's Theory of Evolution

The idea of organic evolution was put forward in the form of a definite theory in the beginning of the nineteenth Century by Lamarck. Lamarck's name, therefore, occupies an important place in the history of the evolutionary principle although his ideas about the mechanism of evolution have been found to be erroneous. (FIG. 28).

The first requirement for the origin of new species is the occurrence of variations. After new characters and features have appeared due to one cause or another, the second requirement is that these variations should be transmitted by heredity to the future generations. If new characters appear in an individual and then disappear with the death of the individual in whose body they appeared, they will not bring about evolution. It is also to be noted that most organisms are characterized by a remarkable degree of adaptation to the environment in which they live. Animals and plants living in water possess special features which enable them to live successfully in water. Land animals and plants lack these features and therefore cannot live in water. On the other hand they have other features which help them to live efficiently on land. These features are absent in aquatic organisms. Animals and plants found on high mountains, in hot and dry deserts, or in dense, humid, tropical forests, differ from one another and have their own characteristics. Lamarck believed that the constant influence of the conditions in which the organisms lived, generation after generation, modified them in such a way that they acquired characters which enabled them to live successfully in these conditions. He also believed that, after certain organisms had lived in the same environment for many generations, the variations or characters they acquired became hereditary. That is to say, the acquired characters of the parents could be inherited by their children even if they stopped living in the conditions which had produced them. This principle of the inheritance of acquired characters is an important part of Lamarck's theory of evolution.

Lamarck thought that new organs evolved in response to new needs continuously felt by the organism. They developed more and more as a result of constant use and exercise. Lack of use resulted in the reduction of organs which became vestigial or disappeared completely. These ideas are often expressed in a condensed form in such expressions as "function creates organ" and the "theory of use and disuse".

Lamarck's explanation of the origin and evolution of organs and their reduction involves the principle of the inheritance of acquired characters. That the influence of environment and use and disuse can produce certain modifications in organs is easy to understand although the quality and quantity of these modifications are debatable. Tanning of skin due to exposure to the sun and the development of strong muscles as a result of proper exercise are well-known. Such modifications or acquired characters can have evolutionary value only if they can be transmitted to the next generation. Can these characters acquired by an individual in his own life-time, either by the influence of environment on his body or as a result of his own effort, be transmitted to the next generation? You know the mechanism of inheritance. The bearers of the hereditary factors are the chromosomes and genes which are transmitted to the next generation through germ cells. New characters can be inherited only if they are due to or accompanied by corresponding changes in the genes in germ cells. There is no evidence available up to the present time to show that when the skin of an individual is tanned by exposure to the sun or when the muscles develop in response to exercise, his genes concerned with these organs also become modified in a corresponding manner. Modern biologists, therefore, conclude that such acquired characters are not inherited. Since the principle of the inheritance of acquired characters is not accepted by biologists today, Lamarck's theory may be considered as out-of-date.

Darwin's Theory of Natural Selection

In the history of the theory of evolution no other name is better known than that of Darwin (1809-82). (FIG. 28). He is so intimately associated with the subject that Darwinism is often considered as synonymous with organic evolution itself. The publication of Darwin's book entitled "The Origin of Species by means of natural selection" in 1859 marked the beginning of a new era in the history of human thought. This book on evolution has been the cause of an intellectual revolution in many branches of human knowledge. The principle of evolution had until then been discussed and debated among a few scientists only. It was Darwin who not only suggested an explanation but also presented the idea of evolution to the world at large. The opposition was tremendous. But the overwhelming mass of evidence presented by Darwin eventually helped him to victory.

Darwin noted the prodigality of reproduction in organisms. "There is no exception to the rule that every organic being naturally increases at so high a rate, that, if not destroyed, the earth would soon be covered by the progeny of a single pair". Some fishes lay millions of eggs. "An oyster may have 60,000,000 eggs. If all the progeny of one oyster survived and multiplied and so on until there were great-great-grand-children, these would number 66,000,000,000,000,000,000,000,000,000,000,000 and the heap of shells would be eight times the size of the earth".

The potential rate of the reproduction of animals and plants is really staggering. But in proportion to this rapid rate the actual increase in population of any species from one generation to the other is not much. This is due to the large number of deaths in every generation. Large number of births, on the one hand, and limited food and space and other requirements of life, on the other, combined with unfavourable environmental conditions, result in keen competition. There is a hard struggle for existence among the individuals. All the individuals of a species are not alike. Even brothers and sisters show differences or variations among themselves. Some of these variations may be of advantage in the struggle for existence, others may act as a handicap and still others may be of indifferent value in the struggle. In the struggle for existence individuals with favourable variations will succeed. They will have a better chance of living and reproducing. Those with unfavourable variations will be defeated. Their chances of living and reproducing are minimized. The next generation will show a preponderance of individuals with favourable variations and a smaller number of those who do not possess such variations. This natural selection is repeated in every generation. It results in the survival of the fittest and the elimination of the unfit. Natural selection thus leads to the origin of species which are well adapted to the conditions of their life.

The theory of the origin of species by means of natural selection may be briefly stated thus. Rapid rate of reproduction, on the one hand, and limited food and space and various other conditions of life, on the other, result in a struggle for existence. The struggle for existence leads to the natural selection of individuals with favourable variations in preference to those with unfavourable or indifferent variations. This is repeated in every generation. Natural selection thus brings about the gradual evolution of new species from those already in existence.

There is no place here to consider the various criticisms against Darwin's theory of natural selection. It has its limitations. It should be enough to state that later investigations have modified Darwin's opinions to a lesser or greater extent. Some have given the name of "neo-Darwinism" to the modified form of Darwinism. It should be noted, however, that the essential feature of Darwinism, that of natural selection, has withstood successfully much of the criticism hurled at it. Even the latest researches have confirmed the essential features of the principle of natural selection.

Weismann and the Inheritance of Acquired Characters

Gradual changes or variations occurring in each generation and preserved by natural selection eventually lead to adaptation or to the origin of species adapted to their environment. Do these variations arise as a result of the influence of environment on the body or due to use and disuse of organs? If so, can such variations be inherited? Both Lamarck and Darwin answered these questions in the affirmative.

Weismann, a keen student of Darwinism, paid more critical attention to the problem of variations that are the basis of evolution. (FIG. 29). According to him the body of an organism is divisible into two parts. One of these consists of the cells that take part in reproduction and give rise to the next generation. These are the gametes, sperms in the male and ova in the female. Collectively the gametes may be called the germplasm. The other part consists of all the cells constituting the rest of the body and taking part in nutrition and growth during the life of the individual. These cells are collectively called the somatoplasm. While the body of an individual dies sooner or later, the germ cells escape death by leaving the body, while it is alive. The male and female germ cells unite and then develop into a new body. This new body also will die but its germ cells, instead of dying, will give rise to another body. This is repeated in every generation. Thus, there is a continuity of the germplasm from generation to generation. Since it is only the germplasm that is transmitted from parents to offspring, any factors governing inheritance must be contained or must originate in the germplasm. A new variation produced in an individual by environment, use and disuse or some other agent, can be transmitted to the next generation only if it has modified directly or indirectly the germplasm. The influence of environment producing adaptative variations or characters acts only upon the body. The characters acquired by an individual during its own life time, or the so-called acquired characters, cannot, therefore, be inherited. This is in essence Weismann's principle of the continuity of the germplasm on the basis of which he explained inheritance. All his ideas are not accepted today in their original form. Biologists, however, agree that acquired characters are not known, so far, to be inherited and, therefore, cannot explain evolution. The origin of variations leading to evolution will have to be explained differently.

De Vries and the Mutation Theory

The origin of new varieties by their sudden or spontaneous appearance in the evening primrose observed by De Vries has been mentioned earlier. (FIG. 28). De Vries was so much impressed by his observations that he concluded that evolution proceeded not by slow, gradual changes but by large, spontaneous and hereditary changes which he called mutations. Many of the strains of the evening primrose considered new by De Vries were not really new. But his principle of mutations leading to evolution is essentially sound. Some examples of mutations have already been mentioned earlier. Occurrence of mutation is now known to be a widespread phenomenon observed in many plants and animals. Many mutations have also been produced artificially under experimental conditions.

Meckanism of Evolution—Modern Views

The beginning of the twentieth century is also the beginning of a critical scientific study of the mechanism of evolution. The science of genetics has played an important role in this study. Mendel's principles of heredity, which form the foundation of the new science of genetics, were rediscovered in 1900. All the evolutionary theories discussed in the preceding pages thus belong to the age before genetics. During the last 60 years genetics has made a very important contribution to the study of evolution.

The factors that interact and bring about the origin of new species are variation, heredity, selection and isolation. The terms variation and heredity are now familiar to you. You know that variations are the first requirement for evolution. You also know that heredity is equally important because only variations that are inheritable can lead to evolution.

Variations are of two kinds, environmental and hereditary. The environmental variations, also known as acquired characters, are primarily due to the effect of the different factors in the environment. The causes of environmental variations are relatively easy to ascertain and sometimes they are quite obvious. Since these causes affect only the body, or its organs and tissues, without modifying the genes or chromosomes, their effect is not inherited by the future generation. In China until recently, girl babies were made to wear little iron shoes to prevent the feet from attaining their normal size. Hebrews and Muslims have practised circumcision for many generations. Certain tribes in Africa change their facial features to satisfy their aesthetic sense. For instance, lips are stretched to look like saucers or small plates more or less. In our own country, the ears and nose of girls are pierced to enable them to wear ornaments. (FIG. 31). All these modifications have been practised for centuries. In spite of all this, individuals in each new generation are always born without the least trace of any of them because such modifications have not become hereditary.

There are certainly some environmental factors that can produce hereditary variations. With the help of X-rays you can experimentally produce all those gene mutations that occur in nature. But whatever the change produced, it is transmitted to the next generation through the germ cells. Moreover, such changes are not adaptive in nature. Mutations caused by X-rays are of many kinds. They are not an adaptation to X-rays. The expression, "acquired character", as used by Lamarck, Darwin and others, applies to characters which are not only produced in response to the various conditions of life but are an adaptation to the conditions causing them.

Hereditary variations or mutations are hereditary because they originate either directly in the genes and chromosomes of the germ cells or in other cells which will later produce the germ cells. Hereditary variations are of several kinds. Some are merely recombinations of old characters. Remember how Mendel's principle of independent assortment explains this. Other hereditary variations are either due to various changes in the number and structure of chromosomes or are produced by changes in the genes. Genes are the ultimate units of inheritance. Therefore, gene mutations are of fundamental importance as the source of variations which lead to evolution.

Gene mutations are known to occur widely. A large number of gene mutations have been observed in plants and animals. Many gene mutations have been produced artificially with X-rays. Gene mutations produced in this way are like those that occur naturally. Several examples of gene mutations have already been given. An apparent difficulty in accepting gene mutations as the basis of evolution is that a large number of them are harmful. It should be noted that the species existing today have evolved by selection through many centuries. They have attained a certain degree of adaptation and perfection as a result of this long period of continuous selection. Most of the variations can therefore be expected to be inferior to those already in existence.

If all the individuals possessing all sorts of hereditary variations that appear in them continue to live and reproduce, there will be no clear-cut distinction between species. But all the variations do not actually persist. In nature there is a selection which results in adaptation to environment and also in the appearance of groups of individuals marked out distinctly from others. Natural selection thus results in the formation of new species which are more or less well-defined. But wherever the intermediate, intergrading forms persist, the limits between species are vague and the work of defining species is made difficult.

Even after well-defined species have evolved as a result of hereditary variation and selection, it is possible that their limits may become vague later. This can happen by hybridization between individuals of related species and the production of intermediate forms. Hybridization is known to occur in nature. But hybridization in nature is not as frequent as it might have been. There are various factors that prevent species from hybridizing with one another. This phenomenon, known as isolation, prevents the appearance of intermediate forms and maintains the species as well-defined units. Species not so isolated, or imperfectly isolated, hybridize and produce intermediate forms which tend to obliterate the distinctions between them.

Variations that are hereditary lead to the evolution of new forms of life. Selection tends to lead to the adaptation of the new forms to the conditions of their life and, in collaboration with isolation, makes the new groups of organisms more or less well-defined.

A Review

In conclusion we may review the different theories regarding the mechanism of evolution. Lamarck's theory is no longer taken seriously by biologists because the inheritance of acquired characters has not so far been proved conclusively. Critical experimental studies on the inheritance of variations produced by the environment have yielded only negative results. Inheritance of acquired characters is also the weakness of Darwin's theory and to that extent it was modified by Weismann. Darwin's fundamental principle of natural selection, however, has stood the test of time. It is still valid and is accepted by all biologists. The mutation theory of De Vries has been further elaborated in the light of modern knowledge and mutation has been incorporated into the factors of evolution. The mechanism of evolution as understood at present is based upon the contributions of Darwin, Weismann and De Vries and upon the findings of the new science of genetics in the twentieth century.

The inheritance of variations caused by the environment has not been proved. Evolution does not progress in a purposive manner. Yet, unfortunately, the language used by writers on evolution often gives the impression that environment has guided evolution and that evolution is purposive. This faulty language is particularly evident in popular writings. A careful student should, therefore, be on his guard against such language and should study writings critically.

CHAPTER FOURTEEN

The Origin of Life

The problem of the origin of life on earth has engaged the attention of thinkers in all ages. It is one of the most fundamental and at the same time one of the most difficult problems. Some have conjectured that life originated first on some other heavenly body and was later transferred to the earth. It is not known with certainty that life exists on other planets although some astro-botanists think that there are indications of plant life there. It seems highly improbable that life came to earth from some other heavenly body. Even if this were true, it does not solve the problem of the origin of life. It merely shifts the problem from one planet to another.

In a discussion on the origin of life it would be desirable to define what life is. This is a difficult task. The usual practice is to describe its distinctive properties and to say that living beings are characterized by the presence of protoplasmic cells and by the possession of the power of spontaneous movement, metabolism, growth and reproduction. Living organisms exhibit organization. Even a single cell contains numerous chemical substances and displays an elaborate and highly complex organization. But there is no clear-cut line of demarcation between the living and non-living. There are organisms which cause controversy on this point among biologists. Should they be treated as living beings or as non-living? The answer is not always unanimous. You must have heard of viruses that cause various diseases such as small pox, infantile paralysis, hydrophobia, mumps, measles, common cold etc. Many of them are smaller than bacteria. The interesting thing about them, from our present point of view, is that they are often regarded as intermediate between living and non-living matter. Viruses have the power of reproduction and are therefore considered living organisms by many biologists. But they exhibit no organization like that seen in a cell. They are characterized by extreme simplicity of organization, being simply protein bodies. Simple viruses consist of a single, although highly complex, chemical substance. They can be purified and obtained in crystalline form. Some biologists, therefore, regard them as non-living. The properties of viruses are, therefore, significant in arriving at a definition of life.

One thing about life is to be noted. Today, new living beings arise only from those already existing. When living matter first originated many millions of years ago, it must have originated from non-living matter. But nothing like that is known to be happening now. The so-called spontaneous generation of living beings, such as maggots and flies from rotten meat or dung, frogs and worms from mud, or various organisms from dust and dirt, has been experimentally and conclusively proved to be baseless. Conditions on the earth have been constantly undergoing changes from the earliest beginnings to the present day. A particular condition, once gone, is gone for ever. There has been no exact repetition of any state existing at a particular time. The conditions of the earth under which life first appeared have not been repeated again. Life, therefore, originated probably once in the distant past and, since then, it has maintained itself by its power or reproduction or self-perpetuation.

It is believed that living matter originated from non-living matter. Living matter does not contain in it even a single element that is not found in non-living matter. But it is also true that some of these elements occur in living organisms in the form of compounds which are not found outside the bodies of living organisms. Chemical compounds found only within living organisms are called organic compounds. These include various kinds of carbohydrates, fats and fatty substances and proteins. Since all organic compounds contain carbon, they are also called carbon compounds. All carbon compounds may be called organic compounds but a few are usually treated as inorganic. This suggests that the line of demarcation between inorganic and organic compounds is not as sharp as it seems to be. In olden times many thought that organic compounds were synthesized in living organisms by means of a vital force. To this vital force were attributed properties that made it more or less a supernatural force, controlling and guiding the life activities of living beings. Many earlier chemists tried to synthesize such organic substances artificially in their laboratories but they failed. This failure was supposed to confirm the theory of vitalism. It was taken to prove that living matter was fundamentally different from non-living matter, that vital force was a force fundamentally different from all other forces and that it was something beyond the reach of man; man could not understand it, imitate it or control it. The vital force theory, however, was short-lived.

In the year 1828, Wohler succeeded in synthesizing artificially, from inorganic constituents, an organic compound known as urea, found in the urine of man and some animals. This was the first blow to the theory of vital force. The list of organic substances synthesized artificially by chemists began to increase rapidly. And, equally rapidly did the theory of vital force begin to weaken till it was completely ousted from the domain of science. The artificial synthesis of organic compounds, formerly obtained only from living organisms, is now an ordinary everyday affair in chemical laboratories. It is true that there are still many organic compounds which have not been synthesized by man. But whatever success has been achieved shows that there is no fundamental difference between organic and inorganic compounds, that the forces governing the formation of organic substances are as natural as those governing that of the inorganic. Chemists have achieved success after success. They are hopeful that in future they may succeed even with those substances with which they have not succeeded so far. It seems to be only a matter of time.

Perhaps it may never be possible to know how exactly life originated or what were the actual steps through which non-living matter passed to become living matter. Even when chemists succeed in artificial synthesis of protoplasm, they cannot be sure that nature also followed the same method as the one followed by them and not some other method. Several scientists have offered probable explanations of the origin of life. However, all that has been suggested concerning the steps by which non-living matter has evolved into living matter is highly speculative. Moreover, these steps can be understood intelligently by expert chemists alone. At this stage, we need not, therefore, worry about this speculation. All that we should remember is that life phenomena are as much a part of nature as other phenomena. We have seen that the history of the present day plants and animals can be traced back to simpler and simpler organisms that existed in the distant past till we reach the simplest forms of living beings. Do we come to a dead stop here? Or, can we proceed further into the depths of time in our work of tracing the history and seeking the origins? Scientists answer the latter question in the affirmative. The continuity that led us from man and other mammals to reptiles, from reptiles to amphibians, from amphibians to fishes and from fishes to the invertebrates and the simplest living organisms, also leads us further from the simplest living organisms to highly complex organic compounds capable of reproduction more or less like viruses, from highly complex organic compounds capable of reproduction to complex organic compounds incapable of reproduction, from complex organic compounds to simple organic compounds, and so on.

Non-living matter evolved into living matter in the form of the simplest living beings. The latter evolved into newer and newer forms till we reached the present day organisms. The present day organisms will continue to evolve in future into more and more forms. The universe exhibits a wonderful continuity which leads the discerning eye to appreciate the phenomenon of unity in diversity.

CHAPTER FIFTEEN

The Moral of Evolution

On hearing about Darwin's theory of evolution, some one is said to have exclaimed: "Descended from apes! My dear, we will hope that it is not true. But if it is, let us pray that it may not become generally known". To many of us the idea of our descent from apes is simply shocking and repulsive. It seems that such people would have accepted evolution only if it did not imply our descent from apes. Perhaps it may satisfy their vanity if we speak of our ascent rather than descent from apes. But let us consider the question from another viewpoint. Does man always behave in a manner superior to that of apes? Many of man's actions and achievements are certainly highly praiseworthy and set him apart from ordinary animals. But let us admit in all honesty and humility that, although human, we often do disgraceful things that no beast would ever do. Very often man commits injustices, crimes and immoralities which no beast would commit. True, man is the only moral animal. But, when he stoops to immorality, he degrades himself to a level lower than that of beasts. Apes are incapable of doing all the good that man can do; they are also incapable of doing all the evil that man can do. Why then should we feel humiliated if we are told that apes were our ancestors? No wise man ever feels ashamed of his humble ancestors or relations. A man is to be respected or disrespected for his own qualities or faults and not for those of his ancestors. Man would deserve no greater respect than he does now even if he had descended from beings superior to him. Many of the greatest men of all ages have descended from very humble ancestors. And idiots will be idiots even if they descended from geniuses. Let us, therefore, shed our vanity. Our ancestry does not make us more or less respectable. We shall be judged by our own deeds and not by those of our forefathers.

Some of you, by now, may be asking yourself: "Why this fuss about evolution?" Yes, why this fuss? There are some good reasons that justify it. Evolution has definitely enlightened us about certain very fundamental questions and, in addition, it has provided some guidance concerning the future of mankind.

Man's ignorance had led him to believe in barriers that did not exist in nature. Knowledge has demolished many imaginary and artificial boundary walls. It was thought at one time that all the numerous kinds of animals had been created separately and independently without any relationship among them. Similarly all the numerous kinds of plants were considered unrelated. People could not even imagine the possibility of animals being related to plants or vice versa. You now know that there is no sharp line of demarcation between inorganic chemical substances and organic, between organic substances incapable of reproduction and those capable of reproduction, between organic compounds capable of reproduction and the simplest living organisms, or, between plant life on the one hand and animal life on the other. The simplest living organisms gradually lead, through a limitless variety of forms, to the highly evolved animals and plants of today. There is a continuity from non-living matter to man. The great diversity seen in nature has, as its foundation, an underlying unity. Nature displays unity in diversity as well as diversity in unity.

The appreciation of the continuity among living organisms, emphasized by the principle of evolution, leads us to a conclusion of great importance. The origin of all living organisms can be traced back to common ancestral stock that existed at the earliest stage. Common ancestry implies relationship among descendants. Therefore, all the animals and plants of the world, however different they may appear from one another, are to be regarded as related. It obviously implies that all the human beings of the world are also related to one another. Whether we are black, white or yellow, Christians, Hindus, Muslims or atheists, Americans, Europeans, or Asians, we are all related, we are brethren. Not only are all men and women of all the world and of all ages (past, present and future) related to one another, but they are also related to all other living organisms. In fact all living beings are related. The unity of life, inspite of all its diversity, is an essential teaching of evolution. This principle of universal brotherhood, in its true literal sense, is established on the firm basis of science and reason by the principle of evolution, and is no longer a mere theoretical and sentimental principle. It has become as real as "blood-relationship" among brothers and sisters. This is one of the greatest achievements of the discovery of evolution of life. It is full of meaning for mankind and its future.

When man, in his ignorance, did not know the inter-relationships between different natural objects, he considered nature to be a confused mass of unrelated things. Since then man has removed this confusion by pointing out the inter-relationships of things. The principle of organic evolution has similarly brought order out of the apparent chaos in the world of living things. It is this order that makes the study of life and living beings easier, more enjoyable and more profitable. Take just one instance. Useful medical researches and discoveries are not all based upon experiments on man. It is not so easy to use human beings for experimentation. Many experiments would impose restrictions on the experimental individuals. Many experiments are painful while others involve dissection or mutilation of the body or even death. Such experiments are, therefore, performed on guinea pigs, rabbits or monkeys. When they produce useful results, caution trials are made upon human beings. Rapid medical advance has been made possible in this way because of a certain relationship between man and monkeys and other mammals. It is because of this relationship that the results of researches on ordinary animals can be utilized, within certain limits, for the welfare of mankind.

Evolution has resulted in the rise of a unique animal, Man. Man is an animal but, like other animals, he has his own distinctive features that make him different from all other animals. He has acquired greater control of, and independence from his environment than any other animal. Man can speak, learn, think and plan with a purpose; man is the only animal with consciousness of responsibility; man is the only ethical animal with a sense of right and wrong; man alone knows that he evolves and he alone is beginning to acquire knowledge and power that can enable him to direct his own evolution. Man possesses a tremendous power both for good and for evil. While he is acquiring power to direct his own evolution, he has also generated weapons for his own annihilation.

Man is the highest creature in the scale of evolution. But there is no reason to believe that he has reached the limit. All life will continue to evolve as long as it exists. So will man. There is nothing in this universe that is not changing or will not change. Every thing must change, slowly or rapidly. Nothing can escape the process of change. This revelation made by the theory of organic evolution has a lesson for mankind. To keep pace with the changing world we have to adapt ourselves to new conditions. We should not stick to the past. Of course we cannot detach ourselves completely from our past. That would not be desirable. All that is valuable in the past should be retained. The accumulated experience of the past should constitute the foundation on which the future is to be built. But the past and all its traditions are not to be worshipped. Even if our past was happy and glorious, let us not decide to continue to live in the past. The future is more important. The future can be made even happier and more glorious if we strive for it. Humanity is on the march. Man has conquered the earth, has created artificial satellites and planets and is now on the way to conquering the universe although he has not yet conquered his own self. The past is gone; let us look forward to the coming future and struggle to make it happier for everybody.

Evolution has proceeded from the old to the new and its general trend has been progressive. It cannot be argued from this that all that is old is bad and every new thing is desirable. Evolutionary history itself warns us against this attitude. Evolution has often led to degeneration or complete extinction. Change is inevitable. But let us not be fascinated by mere change. Change for the sake of change alone is meaningless. We have to consider whether we should change for the better or for worse. Some new scientific achievements and social trends are capable of leading to the complete destruction of mankind. If it is desired that further evolution should result in cultural progress and greater human happiness, mankind will have to act with due thought, responsibility and broadmindedness and will have to pay due regard to ethical values.

In the ages before life came into existence, there was only cosmic evolution. This brought about the elaboration of various forms of matter. Cosmic evolution culminated in the evolution of highly complex organic compounds capable of reproduction. This stage in cosmic evolution initiated a new kind of evolution, the biological evolution or the evolution of life. Biological evolution culminated in man who can think, judge and plan. He acquires knowledge which can accumulate through the ages. Inheritance of this accumulated knowledge of the ages does not involve the chromosome mechanism. At this stage of evolution biological evolution initiated a new kind of evolution which has been called the human or cultural evolution. Does biological evolution provide any lesson for guidance of this new evolution? Yes, it does, provided it is studied intelligently.

Some students of evolution have interpreted too literally the principle of the struggle for existence and natural selection leading to the survival of the fittest. They say that evolution teaches us that human evolution will also depend upon the struggle for existence leading to survival of the fit and elimination of the unfit. Does it mean that we should entertain feelings of hostility towards one another, always ready to kill those whom we do not like or consider inferior to us? Some believe in the absolute superiority of their own race or their opinions, religious, political or otherwise. They think that every one must conform to their dictates, the other alternatives being either their subjugation or extinction. They forget that the struggle for existence does not always mean fighting and killing. It is not always a struggle among individuals but often a struggle against the environment. There is, of course, bloodshed and killing in nature. But evolution teaches us that new situations and problems need new solutions. Human evolution has attained a new level and demands new attitudes. This is the lesson that we should learn from the evolutionary history of the past instead of blindly accepting it as an absolute guide. Many new features have come into being with human evolution. Progress now depends more upon co-operation than upon hostility. The slogan of every individual for himself, or every family or group for itself only, might have been all right in the past. If the continuing process of evolution is to lead to happiness, entire humanity will have to act as a family bound by love and sympathy, not torn by unhealthy competition and hostility. The best example of progress based upon co-operation, and not upon hostile struggle, is provided by science itself. The rapid progress of science in recent years is based upon the spirit of cooperative thinking, mutual consultation and international cooperation among the scientists of the world. If scientists of every nation had kept themselves in isolation, science would not have achieved what it has.

Mere survival can no longer be regarded as the criterion of fitness as far as human evolution is concerned. The greatest scientists, philosophers, writers, statesmen or social reformers are neither among the strongest men nor are they always among the most reproductive. In a purely biological struggle for existence many of them may prove unfit for survival. To ensure the continued advance and happiness of human society it is essential to discover and to take special care of the talented people although they may be weaklings biologically. An ailing Darwin or Einstein can be more useful to society than a mere Mr. Universe.

Is it possible or desirable to formulate a uniform code for further evolution for all mankind? Evolutionary history tells us that in every age, evolution has proceeded not along one line but along many different lines. Every line leads to adaptation to life conditions in its own way. Evolution leads to diversity. Evolutionary principle should not therefore be used to justify enforced uniformity or regimentation in society. Evolution does not justify authoritarianism or totalitarianism. Let myriad flowers bloom and let myriad schools of thought contend, without bloodshed or bitterness. Let no one enforce his faith and beliefs, political, religious, academic etc. on others.

It is not possible to prophesy the direction and form of human evolution in the future. Such evolution will certainly give man steadily increasing command of his environment and sharpen his intelligence. While he has acquired a fair degree of knowledge concerning his body in general, his mental powers are yet to be fully understood and utilized. Mental processes will have to be investigated more thoroughly and their future possibilities explored. The subject of telepathy is still controversial. There is enough evidence, however, of the remarkable control that mind can exercise over the body. Hypnotism and psychiatry give some indication of how mental powers can be utilized for man's welfare. Evolution will perhaps lead to greater development of man's mental powers in future.

Does the evolutionary principle set a goal for further human progress? No. Mankind has to provide himself with his own goal and purpose. He has already done it. Lasting happiness for all mankind is the obvious choice. But many individuals and nations still believe in their own happiness at the cost of others. There are others who believe in bringing happiness to all mankind but there is a good deal of difference of opinion about the best way of achieving this. There is bitterness, suspicion and hostility. Mankind is divided into warring camps. On the one hand he is trying to fly into outer space to conquer other heavenly bodies and, on the other, there is the possibility of his complete self destruction by his own inventions. Let us hope that, with further evolution, mankind will acquire an increasing degree of wisdom, greater disinterestedness and fuller control of emotional impulses. And let us hope that this will lead to a future in which all human beings will live in harmony, peace and happiness.

Part III

THE EVOLUTION OF MAN

CHAPTER SIXTEEN

The Ancestry of Man

Life is a Unity

The weakness of lauding ones own species to the skies is peculiar only to man. He considers himself to be the "pride of creation", the deputy of God on earth. Man is undoubtedly the highest and the most complex form of life so far, and has reached the highest rung of the evolutionary ladder. It is also true that great possibilities of the advance of man in society exist. But all this certainly does not mean that the human race is fundamentally different from or unrelated to other living beings. Man is just the last link in the continuous chain of organic evolution. Howsoever different the present and the future of man may be from those of plants and animals, yet they have a common past. It is therefore necessary to study the story of human evolution as an integral part of the story of the evolution of life.

Our Family Tree

You must have heard discussions about genealogies especially when a marriage is being negotiated. Long forgotten matters are dug out of oblivion! Old grandmas, turn surgeons, conduct post-mortems using their tongues for knives: the girl's grandfather's younger maternal aunt was not of pure blood, and, therefore, marriage cannot be solemnised; we shall not let such blemish taint the good name of our family. And, in order to prove the unsullied nobility of their blood, a long, moth-eaten scroll is fetched out of an antique chest. This scroll reveals a tree-like figure drawn on its surface. At the root is the name of the prime-ancestor. This root breaks up into a number of stems bearing the names of the prime-ancestor's children and grandchildren. Each of these stems is further subdivided into smaller branches. If you look closely, you can find your own name inscribed on some small branch; and, this branch, too, will in time, produce new shoots.

This is how the genealogy of any one family is compiled. We, however, are writing the story not of one family, but of the entire human species. And, according to custom, we have to begin by stating the lineage; the story will, otherwise, be incomplete. The question we are now faced with is: How should the genealogy of Man be described?

It is not a matter of two hundred or three hundred years. The story of human species goes back to a million years. This period might seem excessively long to you; but it is insignificant in the life of our Earth, whose story is so long that the mere thought of it makes one dizzy. Geologists have compiled this story with much toil and diligence. It was an arduous job; for it was not the story of men that its sources could be traced to the verbal tradition or to the written word. Poor Earth can neither speak nor write. How was its history to be written, then? It is, indeed, a tribute to the mind of man that it could resolve this riddle. He argued that past events must have left some marks on the surface of the earth; and that by studying these closely, one should be able to learn much about its history.

Long before Man came into existence, life was present on this earth in the form of multifarious plants and animals which kept on becoming extinct and being replaced by newer ones. This caravan of life has been marching on for billions of years, leaving behind its footprints on the path. How are we to study these footprints in order to compile the history of life on our planet? This problem has already been studied in a previous chapter. We have already seen how fossils were formed and how with their help geologists have been able to discern five distinct eras in the history of life—the Archaeozoic, the Palaeozoic, the Mesozoic and the Cenozoic.

Since at this stage of our study we are concerned with the emergence of man, we shall focus our attention on the last of these eras, when the class of mammals, to which man belongs, dominated the scene.

The Era of Mammals

The Cenozoic era or the era of modern life had its remote beginnings about seven crores of years ago. It is also called the the mammalian era because it has been during these seven crores of years that this new class of living organisms, has fully developed and gave rise to their highest form of organisation—the *Homo Sapiens.*

Mammals are genealogically related to those reptiles who had started caring for their offspring and whose bodies had begun to develop milk-secreting organs as early as the closing years of the Palaeozoic era. But the Mesozoic era proved to be a time of great hardships for them. Gigantic animals ruled the land. These early mammals who were fond of their young ones, managed somehow to live near the marshes or hid on the branches of trees. Death, in the shape of Tyrrainosauri and their kith and kin awaited them on all sides. These smaller animals, however, had discovered the secret which ensured not only thin survival but also their evolution. That is why the revolutionary changes of the early Cenozoic era, which wiped out the gigantic reptilian order as if it had never existed, left these puny mammals unscathed; and in time they became the masters of this globe.

What are the chief characteristic features of the mammalian class which differentiate it from the preceding forms of life? Obviously, the most important of these, is the presence of mammary or milk-yielding glands. Only the mammals have such glands.

Unlike the reptiles or birds, mammals do not lay eggs outside their bodies. Their egg passes through the early stages of development within the mother's womb and comes out in the form of an offspring.

We know of some organisms which, from the point of view of these features, may be considered to be the connecting links between reptiles and mammals. The duckbill and the platypus are good examples. They possess mammary glands like mammals but lay eggs like reptiles. Unlike developed mammals, they do not have breasts or teats. The milk secreted by the mammary glands moistens the hair surrounding those glands and the offspring satisfy their hunger by licking the hair.

The Paleocene

The Cenozoic era has been subdivided into seven epochs. In the first epoch of the Cenozoic era, the mammals developed along new directions under the conditions created by the cataclysms of the early Cenozoic era. During the 15 million years of the Paleocene era, they could fearlessly prowl among bushes and in the forests since their mortal enemies had become extinct. This change revolutionised their way of living.

The early mammals of the Paleocene epoch were very short in stature. They lived mainly on small insects. Let us introduce you to one of their interesting specimens, *Periconodon*. It had a mongoose-hog on all sides. It was such animals as these who, proceeding on the path of evolution, were transformed into the useful mammals of today.

As the Paleocene epoch was nearing its end, life took a new turn. Forms belonging to an important evolutionary stem thrived. This was the stem of the family of Primates, whose most advanced representative is Man. But the early primates were very different from us. Take, for instance, *Plesiadapis*, who could climb trees, had a hairy skin and a conspicuously long tail. Whether you like it or not, this tailed quadruped animal occupies a very important place in our ancestry.

The Eocene

The second epoch of the Cenozoic era is called the Eocene epoch. It lasted for about 20 million years. In this epoch the family of mammals thrived more particularly and those animals who evolved, in general appearance, resembled the animals of our own times. If you could step into an Eocene jungle with the help of a time rocket, you should see camels of the size of the present cat, rhinoceroses no bigger than hogs and elephants that hardly reached your waist. The diminutive monkeys whom you should see frisking about on the trees would be the specimens of the primate family most intimately connected with the human race.

The Oligocene

The third epoch of the Cenozoic era is called the Oligocene. In this epoch, lasting for ten million years, the race of ancient mammals became almost extinct. Mammals developed along directions which led them to their present forms. A whole army of Rodentia, or gnawing animals, was formed: hares and rabbits gambolled about on all sides. The carnivora were divided into two major categories, and their representatives can now be seen in the form of dogs and cats. The 'vegetarian' animals, too, did not lag behind their carnivorous brethren in the race of evolution. One of their branches evolved to assume the form of horses, asses and rhinoceroses, while the descendants of the other exist to-day as cows, goats, pigs, camels and deer. This is how our distant relative stood in the Oligocene epoch. Let us now study our closer kith and kin. During the Oligocene, primates advanced rapidly on the evolutionary path. The first anthropoids made their appearance on this earthly sphere. This was a significant step towards humanity in the process of evolution. Fossils of two of their representatives have been found in the Oligocene layers of the earth. *Parapithecus*, whose remains were discovered under the layers of a dried-up lake in Egypt, was small in size, but no one can deny his significance in the story of evolution. Some experts believe that he was our prime ancestor. The bones of one nearly related to them were also found in Egypt. Experts have given him the name of *Propleopithecus*. Compared to *Parapithecus* he was bigger in size, and somewhat nearer us on the evolutionary path. From our point of view the appearance of these anthropoids during the Oligocene is of great significance.

The Miocene

Miocene is the name given to the fourth epoch of the Cenozoic era. It lasted for 20 million years. In this epoch mammals continued to progress in the directions already determined in the Oligocene. They went on increasing in size: horses had not become whalers yet, but they could compete with the ponies of today; rhinoceroses looked like a breed of large-sized dogs. The camels of this epoch did not have the clumsy body that they have today; they had a resemblance to deer. The most frightful of these animals was the monster-like boar. In size it equalled an ox; but its skull was four feet long. If you were to see it in a dream, you would wake up with a shriek. Together with these quadrupeds, our ancestors, too, were marching forward. Herds of anthropoid apes began to roam about on the Earth. It is important to introduce you to some leading members of this genus. Meet *Preconsul Africanus*—resembling a chimpanzee, but somewhat smaller than the latter in size. He was trying to stand on two feet. Or take the case of *Paleopithecus*. He is considered to be the ancestor of the present-day gibbons. The anthropoid ape whose remains were found in our own country has been name *Sivapithecus*. His front teeth resembled our own; and a chin, too, had begun to appear. *Dryopithecus* is, however, considered to have played an even more important role than these three. The bones of these animals were found in the strata of rocks in the European and Asian plains. Their position in the family tree is highly controversial, and it has not yet been decided whether they have any direct relationship with man or not. The advance made by anthropoid apes during the Miocene is of great importance from the point of view of human evolution.

The Pliocene

The fifth or the Pliocene epoch of the Cenozoic era lasted for 20 million years. In this epoch, the size of the mammals increased. The Earth once again came to abound in animals, including some reminiscent of the terrible reptiles of the Mesozoic era. Rhinoceroses, lions, sabre-toothed tigers and hippopotamuses established their sway over plains and forests. Anthropoid apes, too, kept on progressing on the path of evolution. Now the story of the origin of life and its evolution is nearing its end. We have to devote more attention to the sixth epoch of the Cenozoic era—the Pleistocene. The million years of the Pleistocene may seem short in the long history of the earth; but from our point of view this epoch is momentous; for it is during this epoch that man emerged.

CHAPTER SEVENTEEN

The Curtain Rises

The Stage is Set

You must have read plays; and you must have also noticed that in the beginning of each act the dramatist gives a number of stage directions: "This is a sitting room. A door, opening on the right, is hidden behind a red curtain. Before the door sprawls an easy chair. The stage is filled with dim blue light. The hero enters, dressed in a black serge suit."

We, too, have to write the drama of the advent of Man on Earth in the sixth, or the Pleistocene epoch of the Cenozoic era. It is, therefore, important to begin with stage directions. What was this world of ours like when man appeared on it? How was the stage set when our hero, dressed in nature's attire, made his debut?

To construct such a stage setting we shall require slabs of ice; for during the Pleistocene Age the greater part of Asia and Europe lay concealed under ice sheets. Glaciers had slid from the mountains into the plains. A considerable area of the surface of the earth was attired in spotless white. That is why this age is also called the "Ice Age".

How We Came to Know of The Ice Age

Today the fact that our earth had to pass through an Ice Age is admitted by all hands. No one denies that about a million years ago it had to encounter violent climatic changes; that during this period cold reached such extremes that nothing but ice could be seen over vast regions of the earth. And yet, till about a hundred and fifty years ago, people had not even heard of an ice age. Even the scientists who, on the basis of their research, had come to know of the major climatic changes during the Pleistocene epoch were silent; one has to be uncommonly courageous to come out before the world with an original idea

—who could forget Galilio's fate! Schimper's scientific researches has convinced him that glaciers covered the plains of Europe during the Pleistocene epoch; but he feared that if he gave expression to his thoughts, he would be laughed at by his contemporaries. So, in order to affirm what he had to say, he sought refuge in poetry. His poem "Die Eiszeit", which was published in 1836, presented for the first time a picture in verse of the Ice Age. A year later Agassiz, one of the associates of Schimper, ventured to present his views before an association of scientists. This occasioned an uproar and the opponents did not bother a trifle to repudiate Agassiz's thesis. But facts are stubborn things. Agassiz and his collaborators provided such overwhelming evidences in favour of their theory that the voice of opposition was stifled, and the existence of the Ice Age became an established scientific fact. There came to be unanimity on the view that the beginning of the Pleistocene epoch had been marked by bitter cold, the temperature had begun to fall; snowstorms blew in full blast; and the area of permanent snow on the mountains had been considerably extended. The glaciers slid hundreds of miles below in the valleys. The northern regions were completely hidden under the snow.

The Advance and Retreat of the Ice

In 1854, Marlot's investigations opened a new chapter in the research concerning the Ice Age. Studying Pleistocene beds around Durnten, he came upon a startling scene. There were layers of these beds beneath one another; but while the uppermost as well as the lowermost layers disclosed fossils of plants and animals which could flourish in a cold environment, the intermediate layers presented an altogether different picture. In these layers were found the fossils of animals and plants which could in no way have survived the cold. Marlot was, naturally, astounded—for this was as amazing a discovery as discovering a red rose in the snows of Siberia. These imprints of plants and animals were a new challenge to experts. Some of them, however, kept clinging to their old view, but some scientists earnestly started revising their ideas about the climatic uniformity during the Ice Age. Two members of this group--Penck and Brunckner—need special mention. They made an entirely fresh study of the valleys of the Eastern Alps: and came to the conclusion that glaciers advanced and retreated four times during the Ice Age. That is to say, the Ice Age was not a period of uniform cold, but one of violent climatic changes. A warm phase was followed by a cold one, which, in turn, gave way to a warm phase again. We, too, experience a similar change of climate every year; with the arrival of October our woollens, quilts and blankets are pressed into service; and as March comes, they are again restored to their boxes. Some such conditions were obtained during the Ice Age also;—but with a big difference: when winter came, it stayed for hundred of thousands of years; and when it was followed by summer, that, too, lasted for as long. From the point of view of changes in climate, the Ice Age can be divided into various periods as shown in the table below:

Period	*Duration in Thousand of Years*	*Age*
Modern	8	HOLOCENE
Fourth Glacial period	80	PLEISTOCENE
Third Inter-Glacial	1 million to 80	
Third Glacial	1 - 20	OR ICE AGE
Second Glacial	4 - 60	
First Inter-Glacial	5 - 60	
First Glacial	6 - 20	

The Wooly Mammoths

The cold environment of the Ice Age seriously imperilled the lives of animals. Accustomed to the congenial surroundings of the Plaeocene, they could not withstand the bitter cold and the perpetual snows of the Pleistocene, and many of their species became extinct. The sabre-toothed tigers, for instance, perished for ever. What do we do in a similar situation? When winter comes we protect ourselves against icy winds by putting on woollen coats and furred gowns. But in that age there were no mills that could manufacture woollen clothes, blankets or sweaters for the animals. In this state of helplessness nature came to their rescue, and clad their bodies in natural robes; the skin of some species of animals was covered with profuse, long hair which were in no way less comfortable than our over-coats. The most notable of these furred animals were the mammoths clad in coats of brown wool, the long-tusked elephants were the sovereigns of the Ice Age. This species became extinct thousands of years ago; but their carcasses can still be found in the icy regions of Siberia. Lacs of years ago, a herd of mammoth elephants had got stuck in the marshes of this region. Their bodies were covered by layer after layer of snow. The elephants were thus preserved in this natural refrigerator. Only a few years ago, Russian scientists dug out the dead bodies of these elephants from under the layers of snow.

Man Enters the Scene

For our immediate ancestors, too, this was a period of great ordeal. The tropical forests, which were their abode, could not withstand the cold and had withered away. Not a trace of fruitage was left. What were they to eat now? For them it was a very trying period; a large number of them perished; while some migrated to the warmer southern regions, as the forests, too, had shifted thither. Their descendants continue to this day to be apes, and you can still see them in the tropical forests. But there were some madcaps also who, even in the face of all these calamities, refused to leave their ancestral land. They had a bad time of it, as they were forced to change the very pattern of their living. They climbed down from the trees to the earth and started eating herbs and eggs of fowls in place of fruits and nuts. Well, it is not easy to change one's habits of diet. But these anthropoids of the Pleistocene age came off successfully in this test; and they had a reward for it also. A branch of their descendants, marching ahead on the path of evolution, developed into Man.

CHAPTER EIGHTEEN

Down to Earth

Let us study those important anatomical characteristics which differentiate man from the preceding forms of life. What are these characteristics?

Standing on One's Feet

You must have seen in your home an eight-month old baby crawling on the floor. Show him a toy from a distance, and the baby tries to approach you, crawling on all fours. He starts growing up. The mother is worried about how he should learn to stand. The little one himself does not relish this experience: he tumbles down on one side, is hurt and shrieks.

Thank God, that stage is over. The child is a year and a half old, and can stand on his feet. Here comes a new problem: the darling must be taught to walk. A three-wheeler is acquired, and with its help the young one takes its first steps. The sequence of falling down, weeping and crying occurs once again. But look at the father! He is all joy and applause; and the mother's eyes fill with tears of happiness! What is all this merriment about? The boy is learning to walk; he is getting to be a man. Our children succeed in learning this difficult art in a year or two; but imagine the centuries-long training and the fatal experiences which our ancestors had to undergo in order to be able to stand and walk on two feet. In the ever-increasing cold of the early Pleistocene, the fruit-bearing trees had dried up; the vines stood withered; the branches of fig trees were bare; and a time when not a vestige of the fruit-bearing trees was left. What were they to eat now! In sheer compulsion they climbed down to earth. Formerly, they were wont to leap from one tree to another; now they learnt, like children, to walk on earth. But here they were beset with new hardships. Formidable beasts prowled about, ready to devour them. They had to protect themselves from these, and also to search for food. Standing on two feet, they could

CC-0. Agamnigam Digital Preservation Foundation, Chandigarh

see further off and thus become aware of the beasts they had to protect themselves from. For a time it worked well enough: Whenever they spied a beast, they took to their heels. But how long could they keep on fleeing thus and where could they flee to—for there were beasts all around. Necessity begot invention: they devised more effective means of defending themselves against the wild beasts. They found that pieces of stones, scattered on the ground, could be aimed at these beasts in order to scare them away, even to wound them. This, however, necessarily involved standing on two feet; else the stone could not be thrown at any distance. Broken branches of trees were also easily accessible; these could be used as cudgels to assault the beasts. Once again, standing on two feet seemed *imperative*: just try to wield a staff with one of your hands while resting the other hand and the knees against the ground; you will have a job of it; and even if you succeed in wielding the staff, you are more likely to miss the mark than to hit it. The weapons could be used effectively only in a standing position. For a time, stones and clubs continued to be used for defence alone. Experience, however, taught our ancestors that the flesh of the animals they had killed could also be consumed to supplement the short supply of fruits and nuts. Our forefathers had, as it were, tasted blood—both literally and figuratively. Hunting became a part and parcel of their life. Standing as well as running on two feet became an essential feature of their mode of life. This fundamental change in the mode of activity had its repercussions on the entire body. The bow-shaped vertebral column changed to the form of the letter "S". The pelvis became stouter for it had to carry the weight of the upper organs. They became longer, flatter and stronger because they had to bear the weight of the whole body in walking and running.

Forepaws Become Hands

Standing on two feet left our ancestors' hands free. They could use them now to hold or pluck things. Even when they used to live on trees, they had started using their hands to a limited extent. To this day you can see monkeys eating fruits and other things, holding them in their hands. At that stage, however, such a use of hands occupied only a secondary position. It was only after our ancestors had descended to the ground that their hands were used efficiently. The use of primitive implements and weapons had a profound influence on the use and form of the hands: the fingers became longer and acquired dexterity; the thumb was enabled to come in contact with each of the fingers; the grip became more powerful; the arms came to revolve freely on the shoulder-joint; and the ability of holding a thing with one hand and operating on it with the other was acquired. This change opened up innumerable avenues to progress in acts of skill. Nowadays a surgeon can make an incision at such delicate places as the heart; a musician's fingers can manipulate enrapturing tunes; a sculptor can chisel a statue of Venus; and a cricketer can bowl a googly. How did the hands acquire such adroitness? It was by virtue of labour and the use of tools that hands came to be used efficiently and man really became Man. That is why man is also known as a "tool-making animal".

The Transformation of the Teeth

When hands started functioning thus, the load on the teeth was reduced. Our ancestors, while they walked on four feet, used to employ their hands for holding and plucking; but when they started standing on two feet, all these jobs were taken over by the hands. The teeth were, of course, not pensioned off; but their utility was considerably limited. The only function which they had to perform now was to masticate the substances passed on to them by the hands and thus to make them digestible. Tearing and holding required long and pointed teeth; but for mastication alone, short and straight teeth were more suitable. The teeth of the anthropoids are long and projected while those of men are short and straight—so short and proportionate that our poets started comparing the teeth of their beloved to pearls and to seeds of pomegranate.

The Face Changes

The change in the shape of teeth was the first step in a process, which led to the transformation of the whole face. The teeth are fixed in the two jaws; long and projecting teeth required long and projecting jaw-bones; but as the teeth became shorter and straighter, the jaw-bone also started becoming proportionately smaller, till the present features of our face began to appear. The cheeks became symmetrical and round, the lips thin; and a chin appeared.

Man Becomes a Talking Animal

These changes in the shape of the face are very important from the aesthetic point of view; but looked at from the social angle the changes that took place within the mouth were even more significant. The teeth having become smaller, the tongue began to liberate itself of the shackles which had bound it. Why was this necessary? The claims of life had compelled our ancestors to work collectively. It was, for instance, not easy for any individual to confront the mammoth elephants alone. Notwithstanding the crude stone weapons, it was not possible for one man to subdue them. Hunger and the common danger of death taught our ancestors the necessity of collective work. One man was helpless before a mammoth; several, united, could vanquish it. But if work was to be co-operative, one had to communicate ideas to others.

The Language of Gestures

How was this to be done? Well, how do the animals today communicate with other animals or with you? As you enter the home, your dog nestles close to you or it stands before you wagging its tail. The dog is trying to say to you, "Welcome, my master, I have been awaiting you for so long. I am very happy to see you!" You understand him, and respond by patting him on the back, which really means: 'God bless you, Tommy; I am so pleased to witness your love and affection!'

A conversation has taken place, but the tongue has had no part in it. With animals such wordless communication of ideas takes place as a matter of course; but even while communicating amongst ourselves we make use of signs and gestures, and often express our meaning without moving our tongue: we nod our heads if we wish to say "Yes"; we shake it if our answer is in the negative; we bang our hand on the table to express anger.

Our art of dancing, too, makes use of the language of gestures and movements. You see a KATHAK dancer standing on tip-toe, his right foot poised on his left, with his hands in a specific position near his lips,—and you at once know that it is Lord Krishna playing upon his flute.

The Language of Sound

This language of gestures we have inherited from our ancestors. The story goes back to the period when the anthropoid tongue was not as free as ours and there was very little occasion for its movement. The level of social life was so low that oral speech was not necessary for communication. If there was anything to be communicated, gesticulations served the purpose. Impulses, however, were not subjected to control. Sexual appetite, anger, fear, etc. found expression in the articulation of some incoherent sounds. But when our ancestors, having climbed down the trees, adopted their new way of living, the social element became increasingly important in their lives. They realised that there were many things which must necessarily be communicated to others. If a person spied a stag far off, he had to report this fact to others, so that they might all jointly attack it. The tongue was not under control. Therefore, signs and gestures had to be resorted to. To begin with, when the social experience of our ancestors was limited, these simple signs answered the purpose, but the use of implements and weapons raised the level of social life considerably. Work became increasingly complicated in its nature. The new conditions necessitated new modes of communication, and the language of signs and gestures was found to be inadequate. For example, in the darkness of the night signs were of no use; again in the dense forests, where one man could not see another, communication through gestures was not possible. The greatest difficulty, however, was that it was almost impossible to express abstract concepts through gestures. Communication, nevertheless, had to take place, for without it life would have been impossible. Men were, therefore, forced to seek the aid of voice. The bonds which had so far tied the tongue gradually loosened. The structure of throat changed and man came to be a talking animal. The sounds emitted by the larynx ceased to be uniform. A variety of sounds originated: some of these had the mellifluence of honey, while others had the hardness of flint. The accents acquired modulation, and resonance. Wherefrom did the tongue acquire these enchanting qualities? In order to meet the demands of their advancing social life, the bonds which tied the tongue were broken and the process was initiated by means of which man became the 'talking animal'.

The Human Mind

Gesticulating or emitting sounds are purely mechanical acts. Wind a Japanese doll and place it on the floor; it will begin nodding its head and dancing. Wind an alarm clock and place it by your bedside; it will wake you up with its continuous ringing at five in the morning. Be it an alarm clock or a Japanese doll, neither has any volition. If you do not wind them, neither will the doll nod, nor will the alarm-bell ring. But those anthropoids, who wanted to communicate their thoughts to others through their gestures and their voice, had command over their actions. If they beckoned someone by signs and gestures, they did so because they wanted to. To understand these signs, and then to act accordingly is the brain's job. A leaf rustled: the message reached the brain through the ears; the brain ordered the eyes, "look! what is that?" A deer was seen running; the brain decided: "One will not do. Others should be called". The hand made a sign; the throat emitted a sound. The eyes of others saw the movement of the hands; their ears heard the sound. The message reached the brain, which ordered the hands to get ready with the staff, and the feet to run; and whole throng fell upon the poor deer. In this entire proceeding all the organs played some part but the brain had to carry the heaviest burden; for it is like an army general who receives messages from every detachment, and issues commands to each of them. In the initial stages of social living, when there was hardly any need either to understand others, or to make ourselves understood to them, the brain had very little to do. But with the evolution of society, the importance as well as the complexity of collective work went on increasing. To answer these needs our ancestors placed their reliance on voice instead of on gestures; and language came into being. This change put the additional burden of new and difficult tasks on the brain, which started receiving increasingly complicated messages. In the dark of the night somebody said, "we set out hunting as the day breaks". It is darkness all round; there is no indication whatever of the sun; and yet as soon as the message reached the brain through the ears, it created a mental picture of the sun which, emerging out of the depths of the East, provides heat and light. The anthropoid began to think. He became Man. He had acquired control over the power which could conquer his environment for him. Rivers were made to change their courses; waterfalls began to yield electricity; in the deserts of old dancing fields of green crop sprang up.

We have now seen how and when this process started, what stage it has reached: in the freezing cold of the Pleistocene, anthropoids climbed down to earth. Their descendents learnt to stand on two feet, and then began to walk and run with their help. Hands were freed; so they started doing new kinds of work. Social life began to make progress. The language of sounds replaced the language of gestures. The brain started thinking and man began to function as Man.

CHAPTER NINETEEN

The Missing Links

A Fairy Tale

You probably still retain some memory of the good old days of your childhood when on chilly winter nights, with your head snugly covered with your quilt, you used to listen to tales of the *Green Fairy* told you by your grandmother. "My tale is but hearsay," she would begin, "I was no eye-witness to it. In a certain country there once lived a prince—resplendent like the sun, enchanting as the moon. One day he went out hunting with his companions. Descrying a lovely deer, he spurred his horse in its pursuit. The deer ran, faster than the wind. The prince spurred his horse further. His companions, unable to keep pace with him, lagged behind. Mounted on his horse, the prince, by himself, went on in pursuit of the deer. And lo! what did he behold but a grand palace with arches made of silver and domes made of gold! The tired prince entered the palace, the fairy made a sign with her hand, and the prince was turned into a dove . . ."

A Scientific Fact

But the story that we are telling you is very different from the *Green Fairy's* tale. It is not the story of men changed into animals, but of animals evolving into men. It is not the product of the imagination of a fairy story writer, it is a scientific fact. You may well ask for its proof.

In order to furnish such a proof we shall have to examine the various stages which the anthropoids had to pass through in order to evolve into men, and to gather the various links in this chain of evolution. It is a formidable task; for this chain stretches over the one million years of the Ice Age. The ravages of time have destroyed its various links. How much better it would have been if the vogue of building museums had started a million years ago so that this day we could see the skeletons of the anthropoids in various stages of their evolution skillfully arranged in glass almirahs. But, alas, the system of building museums started very late. What we have to do now is to search for each of the links in the evolutionary chain ourselves; to dig up the beds of the Ice Age with the help of spades and other implements. Years of labour yield one solitary tooth which possesses some characteristics of the human and some of the anthropoid tooth. At another place a skull is discovered which is neither completely human nor entirely anthropoid. At still another place a jaw is found which does project, as much as that of anthropoids. These are the missing links which we have to gather and forge into a chain.

The Anthropoid of the South

Let us first of all go to South Africa in our search. In 1938 a school boy was crossing a hillock when he spied a skull peeping through the stones. You, perhaps might have fled on seeing it; but the boy was very courageous. He dug out the skull by hitting at it with pieces of stone and carried it to his home. It was just by chance that the news reached Dr. Broom, who was the director of the Transwaal Museum. Dr. Broom rushed to the school. The boy was summoned. Learning that all this bother had been about the skull he had found, the boy took out four teeth from his trouser-pocket and placed them on the open palm of Dr. Broom's hand. According to Dr. Broom these were the strangest teeth in the history of the world. And no wonder, for they belonged to the Australopithecus, the rest of whose skull had already been found in South Africa itself in 1925.

What They Looked Like

Australopithecuses have a very intimate connection with the origin of human species. Their bodily characteristics are the outcome of the early stages of human evolution, when anthropoids had not quite become men, but were, nevertheless, taking rapid strides towards that stage. They were short-statured, about 4 feet in height; and weighed about 80 pounds. They could stand on their feet and their pelvis had acquired the human form to a considerable extent. The bones of their feet had become like those of walkers on feet. Their fingers were delicate, which goes to show that they did not walk on all fours. Their head stood on their shoulders a little further back than in the case of anthropoids—from which fact we can infer that they could keep their necks straight. All these characteristics had resulted from their walking on two feet. But their resemblance to man stops here. From the neck upwards, they looked more like anthropoids, having big protruding jaws with teeth projecting out, though not as much as in the case of the anthropoids. The bones of their skull were thick and heavy. They did not possess a chin, though its contours had begun to appear. The forehead was sloping, reminiscent of anthropoids. Having studied the features of their face, let us now concern ourselves with finding out the stage of their mental development. But that is not an easy job; for the soft grey matter of the brain soon decomposes, and only the skull remains. It can help us estimate the size of the brain, but does not tell us anything about its quality. You know from your own experience that people possessing large heads are not necessarily embodiments of wisdom. Some of them, indeed, turn out to be so thick-headed as to make you comment in anger that their heads must be filled with cotton wool rather than with grey matter.

Cranial Capacity

We can find out only the cranial or skull capacity of our ancestors, and have no means of knowing about the quality of the brain. We have, therefore, to draw our conclusions about the intermediate stages of human evolution on the basis of a study of skull capacity alone. Let us have a look at the table below, showing the cranial capacity of the present-day anthropoids:

Chimpanzee	(male)	740 c.c.	(female)	440 c.c.
Gorilla	(male)	650 c.c.	(female)	555 c.c.
Man	(male)	1450 c.c.	(female)	1300 c.c.

Where precisely, in such a table, are we to draw the line which will demarcate man from the anthropoids. The British expert Arthur Keith thinks this line can be drawn at 750 c.c. All those species whose cranial capacity exceeds 750 c.c. have crossed the boundary line dividing the anthropoids from man.

Let us study the *Australopithecus* family from this point of view. Their cranial capacity was:

Male—666 to 650 c.c.
Female—440 c.c.

One fact is quite obvious. The members of the *Australopithecus* family had not risen above the anthropoid stage. Judged by this criterion, they resembled the gorillas of today.

The Position in Man's Family Tree

The question now arises as to what position this genus, having conflicting characteristics, occupies in our genealogy. In the beginning the experts were of the opinion that the *Australopithecus* were the common ancestors of both men and anthropoids: that they branched off into two divisions, one of the branches reaching man, the other staying at the level of the present-day anthropoids. That, really was something: it created a sensation in the world of science. The missing link seemed to have been found. But a detailed analysis of their skeletons has disproved this view. Opinion is now almost unanimous that the *Australopithecus* family is not directly related to man. It did make some advance towards humanhood; but had to stop midway after a few steps. You must have come across boys who, somehow, manage to scramble to the eighth or the ninth standard, after which their progress stops and they are obliged to leave school. A similar fate overtook the *Australopithecus* family which managed to reach the elementary stages of evolution, but could not get any further.

Let us proceed further in our search for the missing link. The word *Australopithecus* must have scared you. We shall have to use some more of such names, and these big words may become obstacles in the way of your understanding. Their use, nevertheless, is unavoidable, because as compared with the more familiar terms, their meaning is exact and definite. If you wish to grasp the facts properly, you should try to understand their meaning. Note the meaning of the following two Greek words:

Pithecus means anthropoid, and
Anthropus means man.

Names ending in *pithecus* belong essentially to the category of anthropoids, while those terminating in *anthropus* belong to that of man

Take the word *Australopithecus* itself as an example. *Pithecus* is suffixed to the name. This shows that they belong to the category of *anthropoids*. *Australo* means southern. Thus Australopithecus came to be:

Australo + pithecus = Southern anthropoid

In the discussion which follows, we shall refer to the genus in which the word "homo" is part of the name. The skeletal remains of many of our ancestors, which have been found in the Pleistocene layers, show that although they certainly belonged to the genus "homo", their anatomy, nevertheless, differed from that of the human species. Their specific name generally bears some relationship to the place from which their skeletons were obtained e.g. the skeleton which was discovered at Heidelberg has been named *Homo heidelbergesis*.

The Search in South Asia

Let us now leave South Africa behind in our search for the missing links. To dig out bones from the earth is easy enough; but to determine where exactly the earth should be excavated is very difficult. We have, here, to acknowledge the greatness of the human mind, for in the closing years of the last century, Haeckel, sitting in Germany, formulated the postulate on the basis of these theoretical studies that the missing links could be found in South Asia. Not only that, he even specified the island in South Asia where the bones of our ancestors could be discovered. People who heard of this expressed the view that Haeckel's mind had become weak on account of old age, and that consequently he had abandoned the concrete and real world of science for the imaginary world of fiction. A student at the Amsterdam University, Eúgene Dubois, however, was so much impressed by Haeckel's views that leaving his job and his home he proceeded to South Asian islands to examine the Pleistocene layers in Sumatra. Thousands of tons of earth were dug up. Years passed, but the missing link was not to be found. Any other person would have despaired and tried to unburden his mind by denouncing Haeckel. But Dubois had the spirit of a scientist. He stuck to his guns. Having been disappointed in Sumatra he set out to excavate Pleistocene layers in Java; and here his labour was rewarded.

The Ape Man Who Walked Erect

It happened in 1890. At the foot of the Kendenang hills, in the valley of the river Bengawan, Dubois discovered in the medial Pleistocene layers two teeth, a femur and a part of a skull. Dubois could estimate at a glance the value of these relics. Haeckel's prediction had come true. The missing link had been found. Even a cursory glance showed that these bones were neither entirely human nor completely anthropoid. After his discovery Dubois named the species as *Pithecanthropus erectus*, or, the ape-man who walked erect. A detailed investigation proved Dubois' view to be correct.

How They Were Built

There is no doubt that these ancestors of ours could stand on their feet. Their thigh-bones of femurs were long and straight. They were as tall as a human being, about 5 feet 7 inches. They could not walk as erectly as we do; but human characteristics had already appeared. They could walk with their chest out; so that if you saw them from behind in the fading light of an evening, clad in a suit and promenading on the road, you would not pay much heed to them. But their front would terrify anybody, for, judged by our standards, they had a frightful face. They had protruding jaws without any vestige of a chin, had a broad nose; and a projecting arch made by the bone over their eyes in place of eyebrows. Their forehead was slanting, their skull, too, was like a roof sloping bothways; and they had a short, stout neck. Judged by the external features of their face and skull, they were still far from reaching the human stage; but if we keep in view the changes that had taken place within the cranium, we find that they had advanced a good deal towards humanity. Their cranial capacity measured 940 c.c. In this they had certainly risen above the anthropoid level. Not only was their brain bigger in size than that of the anthropoids; even more important than this was the fact that the

CC-0. Agamnigam Digital Preservation Foundation, Chandigarh

part of the brain which maintains a liaison between the functions of speaking and listening was considerably developed. The one conclusion which can be drawn from this is that they possessed the power of speech. The tongue had broken loose the shackles which bound it. The throat could emit varied sounds. The foundations of social life had been laid. The right half of the brain of these ancestors was more highly developed compared to the left; which means that like us they, too, used their right hand more than their left.

How Is the Java Man Related to Us?

Having studied their physical structure, let us now determine the place to be assigned to them in our ancestry. It is a very controversial problem. Scientists are divided on this matter into three groups. The first group holds that they are directly connected with the human stem; the second maintains that they were only developed from anthropoids, and that they have no direct relationship with the human branch; the third group has chosen a via media. They believe that these ancestors, though certainly related to the human stem, are not directly related. They appeared as a secondary stem in the process of human evolution. These three views can be understood with the help of the illustration elsewhere.

The discussion still continues, though the excitement witnessed in the initial stages has subsided. Expert opinion is gradually moving towards unanimity on the third point of view.

Bones on the Foot of The Chick Hillock

Even while the genealogy of *Pithecanthropus* was being debated, some additional bones of our ancestors were discovered in China. After the First World War, the consensus of opinion among scientists was that the most rewarding place in which to look for the first signs of the human race was Central Asia. In order to substantiate this view with evidence, investigators made the Gobi desert and its neighbouring regions the centre of their attention. To begin with, old layers of the region yielded nothing but huge eggs of Dinosaurs. Those who had set out to find some signs of man returned with only eggs; and those, too, belonging to the gigantic reptiles of the Mesozoic Era. The events in the spring of 1918, however, held out some hope. In those days Anderson was stationed at Peking. He heard a flying report that about forty miles to the South-west of Peking, near Chao Kao Tain, was a hill popularly known as Chi Ko San, or the chick hillock; and that at the foot of this hill were scattered old bones of various kinds. Hearing this rumour, Anderson, accompanied by some other experts, set out for Chi Ko San. Aided by the local population, these anthropologists reached a lime-stone quarry. In the quarry could be seen bones and teeth of deer scattered all round. The experts started examining the quarry more thoroughly. Anderson witnessed a strange phenomenon: in the quarry could be some pieces of .... Anderson was taken by surprise: What had these .... to do with the lime-stone quarry!—these stones must have been brought by the early man from another place. Anderson told his companions: these .... are the signs of the early man; search here and you are sure to find his bones, too. This prediction of the great scientist came true; and on that chickbones' hillock were discovered, well, not chickbones but the bones of some very important ancestors of ours. On 16 October 1926, Dr. Lohan found a huge molar. No one had seen such a curious tooth before. Prof. Black of Peking was amazed to see it. After a thorough examination he declared that the tooth belonged to a genus which, since extinct, nevertheless occupied a very significant place in the process of evolution from ape to man. Black named this missing link *Sinanthropus Pekinensis*. His conduct was severely criticised in some quarters: it was, indeed, extraordinary to build up the whole structure of an animal on the basis of a mere tooth. Later investigations, however, proved Black's postulate to be correct, and even his critics acknowledged the soundness of his courageous stand. On 2nd December 1929, Dr. Pei found a skull peeping through a layer of limestone; it belonged to the genus whose tooth had been found three years ago. The existence of the genus *Sinanthropus* now no longer remained a mere hypothesis propounded by a great scientist: it became a scientific fact.

The Body of the Peking Man

Let us study the anatomy of these ancestors of ours, and assign a place to them in our genealogy. The males of this genus were about 5′-2″ in height, and their women nearly 5 feet. The length of the arm and the thigh of the chimpanzee anthropoids are almost equal but the thigh of man is 25% longer than his arm. The thigh of *Sinanthropus* was 20% longer as compared with its arms; which means that, judged thus, *Sinanthropus* had advanced far ahead of apes on the path of evolution, though it had not yet reached the human stage.

The thigh bone of *Sinanthropus* resembles ours; and there can be no doubt that he could stand and walk on two feet. He had a relatively smaller and projecting face. His girth in proportion to his height far exceeded that of apes. He had a broad nose; and the high bone of the upper jaw under the eyes which causes the roundness of each of our cheeks, was absent. The forehead was sloping, but not as much as that of *Pithecanthropus*. The lower jaw was crude and primitive; but the teeth fixed in it resembled our own: the canines were neither excessively large nor projecting; the incisors were spade-shaped, like those of the Mongols.

Sinanthropus had an average cranial capacity of 1075 c.c. You must remember that the cranial capacity of *Pithecanthropus* was only 940 c.c., while that of *Australopithecus* just 600 c.c. That is to say, *Sinanthropus* was the wisest and the most intelligent race of its time. This is no supposition: we have evidences in support of this view. *Sinanthropus* had learnt to devise stone implements and to make use of fire. To us these appear to be very commonplace things; but think of the mental efforts involved by virtue of which *Sinanthropus* must have learnt that instead of running away from burning forests in dread, he should, through the observation of the phenomenon and through experimentation, learn to use it for cooking and protection against cold.

Sinanthropus and Our Genealogy

What position does this clever conqueror of fire occupy in our ancestry? According to some experts, *Sinanthropus* is directly related to the human stem of evolution, implying thereby that the men of today are the evolved form of *Sinanthropus*. Other anthropologists, however, are not of this opinion. According to them the position of *Sinanthropus*, like that of *Pithecanthropus*, is comparable to a blind alley. Anthropoids continued to advance towards humanity in this blind alley which had been off the highway of human evolution; their path was, therefore, blocked when they had reached a certain stage. As a result, the genus *Sinanthropus*, notwithstanding its remarkable achievements, perished.

The Search in Europe

We have travelled a long way in search of the missing links—from South Africa to Java, and from Java to China. Let us now move towards Europe. We have so far been concerned with the relatively lower layers of the Pleistocene era; in other words, we have been studying the links in the chain of evolution which stretch over the first, the second and the third glacial periods. We are nearing the modern age now; the uppermost layers of the Pleistocene, or the layers of the fourth glacial period, will, therefore, be the centre of our attention. These layers were deposited during the period from eight thousand to eighty thousand years ago; and out of these a number of complete skeletons of our ancestors have been excavated. Till now a mere tooth, or a skull, or a femur belonging to some genus of our ancestors has been the basis of our study; we shall not be hampered by that handicap now: ever so many complete skeletons have been unearthed out of the upper layers of the Pleistocene. Not merely that; it is even possible to make a gradational study of this genus, for its skeletons have been found in the layers from the third inter-glacial to the fourth glacial periods. We can, consequently, ascertain now what changes occurred in the anatomy as well as in the cultural life of this genus during this period of 100,000 years.

The skeletons of this genus were first excavated in 1856. In north-west Germany there is a small valley at the basin of the river Dussel, near the town Dusseldorg, which is known by the name of Neandertal. In this valley was found a skeleton which is of our own genus "homo". It belongs to a different species; and in accordance with the place where it was found, the species has been named *Neanderthalensis*. In everyday language we refer to it as the Neanderthal Man.

Neanderthal Man Comes to the Aid of Charles Darwin

The discovery of the skeleton of the Neanderthal Man occupies a prominent place in the history of evolutionary thought. Darwin's book "Origin of Species" was first published on 24th November, 1854. In this book the idea of Evolution was presented for the first time as a scientific theory. The publication of this book created a stir in the intellectual circles of Europe. Darwin had struck at the root of antiquated thoughts and beliefs, and had tried to direct the human mind on to a new path. Such revolutionary minds are recognised by the coming generations as their prophets; but their contemporaries hurled abuses at them. Darwin's contemporaries, too, were unsparing in their criticism of his views. Finding themselves incapable of answering his arguments, they jeered at him. Wide publicity was given to the fact that Darwin had alleged apes to be the prime-ancestors of man, and was dreaming of discovering the links in the process of evolution from ape to man.

This discussion was at its hottest when the skeleton of *Homo Neanderthalensis* was discovered in the Neanderthal valley. The discovery only served to add fuel to the fire. Darwin's supporters exulted that the missing link had become a fact instead of remaining just a supposition. There was, however, confusion in the opposite camp. Who could deny the existence of this skeleton! The opponents, notwithstanding, proffered some very amusing arguments to sustain their contention. One of them, for instance, contended that the heavy and projecting jaws of the skeleton, or the frontal torus over its eye, must have been the consequence of some disease, and that the skeleton, otherwise, belonged to our own human species. In the world of science, however, the views of such men cannot prevail for long. Soon afterwards, skeletons resembling Neanderthal Man's were found in Spain, Belgium, France and Italy (Europe), in Palestine (West Asia); in Rhodesia (Africa) and in Solo (South Asia). These discoveries of the time silenced all opponents. It is now agreed in academic circles that in the last stage of the Pleistocene the old world was inhabited by living beings who certainly belonged to our own genus, but whose anatomy displayed some characteristics of apes also.

The Body of the Neanderthal Man

Let us study the anatomy of the Neanderthal Man. The male of the species stood 5′-3″ to 5′-5″ high. That is to say, they were coming up to our height. Their femur or thigh bone was slightly curved, which leads us to the conclusion that their knees were habitually bent, for, instead of walking erect, they walked with a certain stoop. They were broad-breasted with a neck strong as a bull's. Their cranium or skull was far heavier and bigger compared to ours; but it was relatively less elevated. The forehead was low and sloping; the face long and protruding; the hollows of the eyes very large; and the nose long and broad. In place of eyebrows they had a projecting bone; their upper jaw was prominent while their lower jaw was very heavy and bulging with just the trace of a chin.

Their skull capacity was surprisingly large—about 1500 c.c. On the strength of this at least the Neanderthal men could lay claim to being men, for their cranial capacity measured more than the cranial capacity of many of us. But in mental development, man is far more advanced than our Neanderthal ancestors. Nevertheless, we may surely infer that the Neanderthal brain is a significant landmark in the transition from the relatively undeveloped brain of apes to the highly developed brain of man.

This wonderful mental evolution was the outcome of far-reaching changes in cultural life. The Neanderthal Man made rapid progress in the art of making stone implements. Besides making this material progress, the Neanderthal Man commenced the metaphysical quest which later on came to be a basic feature of the human mind. They were the first to bury their dead with hands fixed to the sides and knees touching the chin. This is the same posture in which a child is born. Why, now, did they do so? We shall probably never get a satisfactory answer to the question; but we can definitely say that they had started pondering over the problems of life and death: Neanderthal Man was the first philosopher.

The Fall of the Curtain

After the appearance of the Neanderthal Man on the scene, the curtain was once again lowered on the drama of human evolution. This happened twenty-five thousand years ago. Glaciers, having advanced for the fourth time, were retreating. The physical environment was undergoing transformation. In the layers of this period there are no signs of the Neanderthal Man. Why did this happen? Why, after all, did this flourishing Neanderthal genus perish all of a sudden. Anthropologists do not give any satisfactory answer to that. Some more skeletons discovered in future may throw some light on the problem, but for the time being the extinction of the Neanderthal Man remains unexplained.

The Curtain Rises Again

The curtain was once more lifted. The fourth glacial period was nearing its end. Life took a new turn in the plains of Europe. New inhabitants arrived: these were the representatives of the human species, called "Homo sapiens". The skeletons found at Cro-Magnon and Grimaldi resemble our own skeletons. There is, no doubt, some difference; but it is not in essentials. The men whose skeletons these are belonged to our own species, but to a different race. Even today the bodily structures of the Negro and the Mongol race are not the same. There was a difference of the same kind between the men of today and the Cro-Magnon or the Grimaldi men.

The Place of Man in the Map of Life

We have now reached a stage in our study when our own body will be the centre of our attention. But before we do that we must find out the place of *Homo sapiens* on the map of life. If we want to locate a town on the map of the world, what method do we adopt? Obviously, we first of all find out the continent to which the city belongs; then the country in that continent where the city is situated; next the province or the state in which it is located; and lastly the division or district to which it belongs. Let us take Aligarh as an example. Aligarh is situated in the Agra Division of the U.P. State of India in the continent of Asia. We follow a similar procedure to locate the position of a species on the map of life. Karl Linnaeus by devising this procedure, has introduced order in the various divisions of life. To begin with, all living beings have been divided into two kingdoms—the Animal kingdom and the Vegetable kingdom; the *Homo sapiens* is obviously related to the Animal kingdom. This Animal kingdom consists of a number of phyla; *Homo sapiens* falls under the *phylum chordata*. Each of these phyla has a number of sub-phyla; the *Homo sapiens* is connected with the sub-phylum *vertebrata*. Each sub-phylum is divided into classes; the *Homo sapiens* comes under the class *Mammalia*. Each of these classes includes a number of orders; the *Homo sapiens* belongs to the *primate* order. Each order comprises many families; the *Homo sapiens* is a member of the family Hominidae. Each family is split into several genera; the *Homo sapiens* belongs to the genus *Homo*. Each genus consists of a number of species; *sapiens* is the name given to the species of the *Homo sapiens*. These facts are illustrated in the following table:

The Homo-sapiens

Kingdom	—	Animal
Phylum	—	Chordata
Sub-phylum	—	Vertebrata
Class	—	Mammalia
Order	—	Primate
Family	—	Hominidae
Genus	—	Homo
Species	—	Sapiens

The *Homo sapiens*, the product of millions of years of evolution, tries to understand not only the cosmos, but also his own self. He feels his own pulse; counts his heart-beats; strives to unravel the secret of the light in his eyes. Let us prove worthy of our name, *Homo sapiens* or wise man and try to understand our own body with the aid of our wisdom.

CHAPTER TWENTY

From the Age of Mummies to the Times of Harvey

The revolution of the planets, the twinkling of the stars, the fascinating colours of the rainbow and other bewitching manifestations of nature have always attracted man's attention. Even the half-savages of the Stone Age marvelled at the red sphere which made its appearances everyday in the east and bestowed light and warmth upon them. But, imagining his own body to be a familiar object, man took it for granted and did not try for a very long time to discover its hidden secrets.

The Age of Mummies

The first systematic efforts to know the structure of the human body were made during the days of the prehistoric civilizations of Babylon and Egypt. You must be aware of the custom of mummifying the dead in the time of the Egyptian pharaohs. To perform this job skilfully, it was necessary to be acquainted with the structure of the human body. But this acquaintance was obviously, superficial. It served practical needs, but it could not possibly form the basis of any sound theory. The Babylonian and the Egyptian ideas about human anatomy were, consequently, far from being correct, though, they were quite interesting. A few examples will serve to make the point clear. For instance they thought that, while breathing, air entered the body through the nose and, passing through the heart, left the body through the rectum. With them the heart, the womb and the stomach were the centres of various appetites which, if not satisfied, coursed in vexation all over the body and made a man ill. They believed the heart to be the centre of all thoughts and feelings. Old ideas die hard, many people even today imagine the heart to be the abode of our finer feelings in spite of the fact that science long ago proved this view to be wrong.

Egyptian religion and Egyptian science got so mixed up that it is very difficult to separate them. Even their knowledge of anatomy was influenced by their religious ideas. They believed that each organ of the body was under the sway of some specific god. Howsoever mistaken and ridiculous these views might appear to us today, there is no doubt that the foundations of the science of anatomy were laid by the prehistoric Babylonians and Egyptians.

Hippocrates—the Voice of Science

Following the decline of these prehistoric civilizations, the Greeks built up the science of human anatomy on the foundations of the intellectual heritage left by the former. As in other branches of learning, the Greeks occupy a memorable place in the history of anatomy, too. Hippocrates and the other scholars of his school of thought for the first time used the methods of observation and experimentation, in place of mythological explanations, to study the human body and its disorders. For instance, prior to Hippocrates epilepsy was supposed to be a sacred ailment whose causes were believed to lie beyond the reach of the human mind. Hippocrates, however, explicitly stated:

> "I feel that the ailment which is styled sacred does not deserve to be called 'Divine' more than any other disease. This ailment, like other disorders, has its natural causes. People call it 'Divine' because they cannot diagnose it. . . . All things in Nature are equal in the sense that they can be traced to their origins in the past."

This was a new voice—the voice of science. Because of such sound views, Hippocrates has come to be known as the Father of Medicine.

Workers and Thinkers

Shortly, however, this school of thought, which affirmed observation and experiment to be bases of knowledge, began to lose its hold over the learned circles of Greece. Greek Society was built on the foundations of slavery. Manual workers were looked down upon as inferior beings. Living on the wealth created by the toil and labour of these slaves, a small class busied itself with mental work in contentment and peace. This division of society into workers and thinkers proved very harmful to the progress of science. In the sphere of learning, the value of experiment declined because it was intimately linked with the labour of the craftsmen. On the other hand, speculative thinking acquired increased importance. Plato and Aristotle, in place of Thales and Hippocrates, became the new apostles in the learned circles.

In the study of human anatomy and physiology, too, speculation came to take the place of experimentation. A reputed surgeon had, earlier, tried to acquire some knowledge about the structure of the human body by dissecting corpses. His experiments had made it evident that the brain and not the heart was the organ of perceptions and impulses to action. He even mustered courage to state what he had found. But this fact, learnt through experiments, did not fit in with the philosophical system of Aristotle. The Greek mind, therefore, rejected it, and for nearly two thousand years people kept their faith in Aristotle's statement that the heart was the organ of perception.

The Theory of Numbers

The views propounded by the idealist philosophers of Greece about the structure of the human body were founded on abstract thought. Take the case of Philolaus who was a disciple of Pythagoras. Pythagoras recognised numbers to be the absolute reality; and with him the number Four was very holy. Philolaus applied his master's principle to the study of physiology and arrived at the conclusion that there were four primary organs in the human body: reproductive organs, common to all living beings; navel, which was the centre of the vegetative soul; heart, which was the organ of sensations as well as the centre of the animal soul; and the brain which was the centre of the rational soul. These "souls" persisted in physiology for thousand of years.

The Theory of "Four Humours"

However, the doctrine which had a firm hold on the human mind for centuries was the doctrine of Empedocles. This Greek thinker was a great cosmologist. He was of the opinion that the universe was made of four elements—blood, due to fire; phlegm, due to air; choler, because of water; and melancholy, on account of earth. Each of these elements had its distinct quality: earth being cold and dry; air hot and moist; water cold and moist; and fire hot and dry. As long as these elements maintained their correct proportion, a man enjoyed good health; but a disturbance in their proportion made him ill. A similar doctrine had already been developed in our own country many hundred years before the birth of Christ. Sushruta one of the greatest physicians and surgeons of antiquity, and his colleagues propounded the first theory of disease as early as the Seventh Century B.C. This is commonly known as the theory of *Triclosha* or "three humours". According to this a person is activated by air below the navel, by the bile between the navel and the heart and by phlegm above the heart. The presence of these three humours in correct proportion resulted in health, while disturbance of this proportion led to disease.

These views are considered to be the basis of Unani and Ayurvedic medicine even today. They have so deeply penetrated the human mind that even after they have been proved wrong they are expressed in our daily conversation. We still use such terms as melancholic phlegmatic temperament

The Museum at Alexandria

The decline of Athens and Sparta profoundly influenced the intellectual life of Greece. Autonomous city states were replaced by an empire extending to North Africa, West Asia and covering a considerable portion of Mediterranean Europe. Trade flourished; and to meet its requirements special attention was paid to art and crafts. But industrial progress on the strength of speculative philosophy alone was not possible. Of what use could the abstractions of Plato be in the weaving of cloth? Circumstances once again necessitated increased emphasis on the practical and experimental aspects of science. The tradition of Thales and Hippocrates was the state-aided Museum, which was the largest centre of practical research in antiquity, was set up. In this museum, special attention was paid to the study of human anatomy and physiology.

The Contribution of Galen

Galen was one of the ablest men produced by the Museum of Alexandria. The secret of his greatness lay in his endeavour to give a fresh interpretation to the outmoded philosophical ideas in order that they may agree with the facts known through experiment and observation. Ancient philosophers had divided all living beings into three categories—plants, animals and men. Of these, plants possessed only the faculty of growth; animals the faculties of growth and movement; while men possessed the faculties of growth, movement and intellect. Galen, by means of experiments and observation, made a thorough study of the digestive, respiratory and nervous systems of the human organism; and explained the relationship of these systems with the powers of growth, movement and intellect. Thus Galen, brought about the union of practical experimentation and speculative thinking by trying to bridge the gulf which had appeared between the two under the influence of Plato.

According to Galen, the liver and the arteries are the centres of the vegetative life of man. His animal life depends on the heart, the lungs and the veins: while the brain and the nerves form the centre of his rational life. Food gets converted into blood in the liver; this blood is transmitted all over the body by means of arteries, causing growth. Through the arteries blood reaches the right ventricle of the heart where it is purified and its impurities are expelled through the lungs. Pure blood comes to the left ventricle and is carried to the various parts of the body by veins, giving rise to the power of movement. A quantity of pure blood, passing through a network of blood vessels, reached the brain. This blood is further purified in these vessels and by the time it reaches the brain, it acquires the power of mentation. This power is transmitted through the brain to the entire body.

A clear picture of the functions of bodily organs is presented here, and the facts have been fitted into a philosophical framework! This Galenic view of the structure and functions of bodily organs dominated the human mind for one thousand years.

The Dark Ages

The downfall of Greece and Rome was accompanied by the rise of Christianity in Europe. The period in history from that time until the 16th Century is known as the Medieval Period. This was the period of the rise and fall of the Feudal System in Europe. Christianity was the strongest political force. In the dreadful atmosphere of Rome, loud with the savage shrieks of slaves, Christianity emerged as a symbol of humanism and gradually spread over the whole of the continent. It made its influence felt in all walks of life; and the rudiments of a "Christian of Life" began to appear.

This far-reaching influence of Christianity proved fatal to the progress of science. The value of observation and experimentation in the solution of problems was undermined; instead allusions to the Bible and its commentaries sufficed. For example, the learned scholars of the day got involved in a discussion on the problem as to how many teeth a horse had. A series of long harangues and 'thought-provoking' papers ensued; but it never occurred to any one of them to get hold of a horse and count its teeth. That is why the sciences of anatomy and physiology were stifled in Medieval Europe; and erroneous semi-religious, semi-philosophical notions about the structure of the human body prevailed.

Astrology and Incantations

Under the influence of Christianity the Greek view, that God had created two universes—the macrocosm and the microcosm—was presented even more explicitly. Man's body and his soul constituted the microcosm or the little universe; and all that was outside man belonged to the macrocosm. There was an intimate connection between the two; the planets and stars of the macrocosm exerted a profound influence over the different organs of the microcosm. It was, therefore, essential to study the movements of the stars and the planets in order to understand the structure of the human body and the functioning of its various organs. Thus astrology came to replace anatomy and physiology; and charms and incantations took the place of medicine.

Consider the following example of the astrological mode of thinking in the medieval times. Albertus Magnus was a great scholar of the period, and his book, "The Secrets of Women" remained the most popular book on the subject for centuries. The book presented the view that the child in the womb was influenced by different stars and planets in the course of its development, and that the various organs of the body were formed under these influences. For example, the fourth month was ruled by the Sun, under whose influence the human heart took shape; the fifth month was under the sway of Venus, on whose orders the reproductive organs were formed; in the sixth month voice, eyes, hair and nails appeared at the behest of Mercury; in the seventh month Saturn dried the embryo; and, last of all, Jupiter, in the ninth month, provided strength to the human organism.

Such astrological beliefs dominated the minds of men for hundreds of years, and even in the Twentieth Century we have not completely shaken off their influence.

The 'Arab Renaissance

In European history the Middle Ages are known as the Dark Ages; and quite rightly so. The torch of learning and reflection lit by the Greeks had been extinguished by the blasts of blind orthodoxy. In this darkness, a bright ray of light appeared in the Arabian peninsula.[1] During the Medieval Period the Arabs became heirs to the Greek traditions. Several factors account for this. The Arabs were a rising youthful nation which had just begun to breathe in freedom, having liberated itself from the Byzantine and the Persian bondage. A large number of Greek and other neo-Platonic thinkers, fleeing from the oppression of the Church, had sought refuge in the Arab territory. Through them Greek scholarship became a part and parcel of the intellectual life of the Arabs. The Arabs, by virtue of their international trade, got the opportunity to benefit by the ancient intellectual traditions of India and China. Muslim scholars, as against the clergy of their day, acknowledged the importance of experimentation and observation. For these reasons, the period known as the Dark Ages in Europe was a period of unprecented intellectual advance in the regions occupied by the Arabs.

---

[1] The shifting of the centre of learning from the West to the East in the Dark Ages can also be noticed in literature. 'Selections From World Literature' another GERMP publication carries a number of selections from Eastern literature of the period.

As with other branches of knowledge, the Arab physicians did a great deal to keep alive and to advance the science of anatomy and physiology. It is to their credit that we are still acquainted with the names of Hippocrates and Galen. The Europe of the Medieval Period, on the contrary, had thrown the great achievements of these pioneers into the dustbin. The Arabs translated their works and not only preserved this precious intellectual wealth but also enriched it. In this context the names of Rhazes, Averroes and Avicenna must be mentioned. These three were actually medical practitioners. The diagnosis of diseases and their cure was their real aim; but for the realization of this aim, it was imperative to study the human body and its processes. In this sphere, the physicians accepted the views of Galen making them the basis of their achievements. In the study of eye-diseases, however, the Arab physicians sought new avenues. This can perhaps be accounted for by the fact that the desert-dwellers contract eye defects more readily than the people of other regions. In the course of diagnosing and treating these diseases, special attention was paid to the structure of the eyes, with the result that the Arabs were the first to understand the process of seeing. Their researches and experiments made it evident to them that the process of seeing was actually the process of the passing of light through transparent bodies. Ibn-Haytham's name needs special mention in this connection. On the basis of some newly discovered manuscripts it is now claimed that the Arab physicians had even anticipated Harvey and had discovered the important facts about the circulation of blood.

Light Dawns in Europe

This knowledge of the human body was disseminated by the Arabs in Europe. The intellectual atmosphere of Europe had once again become favourable for its reception. The clouds of ignorance had begun to roll away, and the European mind was getting ready for a great renaissance. At such a time the Latin translations of the Arabic books gave a fillip to European thinking. In the universities of Italy in particular, efforts were made to acquire Greek and Arab learning. The value of experimentation and observation was once again recognised. This fundamental change in the mode of thinking was of immense benefit to anatomy and physiology. These researches and experiments culminated in the publication of a monumental work in 1543, which struck at the roots of the Galenic view and gave a new direction to the development of the sciences of human physiology and anatomy. This book which bore the title "Concerning Human Body"; was written by Vesalius, a 28 year old professor at the Padua University.

The Invisible Pores

According to Galen, purified blood reached the left ventricle from the right ventricle by means of minute pores. Vesalius looked for these pores, but could not find them anywhere. Was Galen wrong then? That would have been blasphemy. How could Galen, whose book was as authoritative as the Bible, be wrong! At the same time Vesalius could not disbelieve his own eyes. He was in a fix, and was at last compelled to say:

> "We marvel at the handiwork of the creator. Blood finds its way from the right to the left ventricle of the heart, but through ways invisible to the human eyes."

In the history of science this was not the first or the last case of its kind. It has often happened that the dictum of an authority was given preference over the testimony of the eyes; but even the most tenacious dogma can stand in the face of persistent experimentation. Vesalius's researches could not demolish the Galenic superstructure but they did succeed in shaking it to its foundations. One of his associates, Servetus, went a step further. He stated in plain words that Galen was in the wrong, and that blood passed through the lungs in order to reach the other side of the heart. He was burnt at the stake for speaking the truth. The guardians of established beliefs formed a powerful front against Vesalius himself. His old master Silvius exclaimed angrily: "Vesalius is a profane whose nonsense is spreading venom in the atmosphere of Europe". The only crime of this 'profane maniac' was that he had used his eyes for verifying the truth of accepted beliefs.

Vesalius succeeded in making people alive to the defects in the Galenic view; but he could not present a comprehensive system of his own to replace it. This was left to his disciple Harvey to accomplish.

The Contribution of Harvey

Harvey, an Englishman, was educated at the Padua University. Small machines had come into use in England then. The use of simple machines like pumps, bellows and valves made experimental science an independent branch of learning. Harvey reached Padua steeped in this new methodology of science. There he had ample opportunity to benefit by the researches of Vesalius and his fellow-workers. The synthesis of the English experimental methodology and the Italian descriptive anatomy opened Harvey's eyes. Unlike Vesalius, he did not confine himself to dissection and description, but sought to discover the causes of phenomena—not with the help of abstract thinking, but through practical experiments. As a result of these experiments he could present before the world in 1628 a new and revolutionary concept—the concept of the circulation of blood. He said:

> "We are inevitably led to the conclusion that in animal bodies the blood circulates and is in constant motion. The heart, by its palpitation performs this function; its motion and contraction have no other purpose".

Harvey's name will always be remembered in the history of science, especially in the history of anatomy and physiology. He transformed anatomy and physiology into exact sciences. His hard work and mental labour rid anatomy and physiology of "humours", "souls" and other mistaken and unscientific concepts. He gave to these sciences their scientific methodology: experiment, experiment and only experiment. They made rapid progress after Harvey. The modern view that human organism differs from Harvey's, but progress has taken place on the same lines as were for the first time indicated by his epoch-making researches. This advance was registered by the use of the same methodology which was employed by him in the field of anatomy and physiology. Harvey is both the Copernicus and the Galileo of these sciences.

The Egyptian mummy-makers, Hippocrates, Galen, Vesalius, Harvey—these are the milestones in the history of anatomy and physiology. Scared by the ghost of hours, thwarted by abstract thinking, and handicapped by ancient traditions, the *Homo sapiens*, undaunted by stakes and gallows, has moved on. He who had learnt to read the movement of stars, learnt to understand his heart-beat also. The film that clouded his vision had vanished, and the structure and functions of the human body were correctly understood. These form the subject-matter of the next chapter.

Part IV

WORKING OF THE HUMAN BODY

CHAPTER TWENTY-ONE

Food of the Human Body

The human body is a complicated biological organism. However, for the sake of a simple explanation of its working it is often compared to a machine.

Like the framework, wheels and machinery of a machine the human body has a skeleton which gives it a general shape and protects the delicate organs within. The bones of the head form a protective case for the brain, the sockets for the eyes, and a bony case for the ear. The spinal cord is protected by the back-bone, the ribs and the breast-bone together make a cage for the heart and the lungs. The entire skeleton is made up of about 220 bones—large and small.

The bones are everywhere covered by muscles. The skeleton is the framework of the human body. The muscles use chemical energy for their movement. All muscles have the ability to contract. The big muscles of the arms and legs enable us to move these parts, to walk, to run and to reach for something. The heart muscles pump blood throughout the body. The muscles of the intestines move the food along. Even the expressions on the face are due to the contraction of the delicate muscles. There are about 640 muscles in our body.

A machine gets the energy for its action by burning fuel. The human body converts food into energy. During the production and use of energy, the human body, just like a machine undergoes wear and tear. But while a machine cannot repair its effects of wear and tear, the human body is able to do so by eating food that repairs and builds up the body. So our food is much more than fuel.

The human body requires food to get the supply of the necessary energy to carry on the vital functions such as the circulation of blood by the muscular contraction of the heart, breathing and maintenance of body temperature. This means that some energy is required just to keep us alive. Persons who are doing nothing and are taking complete rest in bed should also therefore eat something to keep alive. It has been said earlier that the food is burning fuel (e.g. coal) and is expressed in calories. (A calorie is the amount of heat required to raise the temperature of one kilogramme (about one seer) of water by 1°C). After digestion and assimilation the food is burnt slowly in the body by the oxygen carried by the blood. The energy thus released inside the body is also expressed in Calories.

Apart from the 1700 Calories of energy which is the absolute minimum required for keeping alive, one needs some more energy for doing his daily work, ranging from sitting and signing papers in an air conditioned office, acting in a film or lecturing in a class to rickshaw-pulling in the blazing sun of May and June. An average adult for his normal daily work requires from 3000 to 4000 Calories of energy depending on his body weight. Persons engaged in more strenuous type of work such as rickshaw-pulling and wood-cutting require energy even upto 7000 Calories.

Food is not meant only for supplying energy. It also is called upon to repair the effects of the daily wear and tear of the body tissues. Food is also required for growth in children. Lasting food maintains the normal temperature of the body which is most suitable for all vital activities.

In order that all these requirements of growth and maintenance of the body be fulfilled we must carefully select our food from a wide variety of things nature has to offer. The following are the main constituents of the food we eat:

1. Carbohydrates
2. Fats
3. Proteins
4. Vitamins
5. Water
6. Mineral Salts

CARBOHYDRATES. These are substances which are composed of carbon, hydrogen and oxygen, although all substances which are made up of these three elements are not necessarily carbohydrates. Familiar examples of this kind of food are cane-sugar and glucose given to patients and convalescents which are of well-known energy-producing value. The starch found in wheat and potato has a rather high molecular weight and is also ultimately broken during digestion into simpler sugars like glucose for supplying energy. Starches and sugars are the main suppliers of energy. The surplus carbohydrates after supplying the necessary energy are stored in the liver as glycogen.

FATS. Butter, ghee and vegetable oils belong to this category. Fats also supply heat and energy and are made up of carbon, hydrogen and oxygen. They are formed by union between one molecule of the well-known glycerine and three molecules of a higher fatty acid such as stearic acid or oleic acid with the elimination of three molecules of water. In the process of digestion, the fats have their constituents broken into fatty acids and glycerine. After digestion and assimilation these constituents are either burned up to supply heat and energy or recombined into fats to be stored as reserve food material.

PROTEINS. The proteins are made up of carbon, hydrogen, oxygen, nitrogen, sulphur and occasionally phosphorus. Proteins are complex substances having a high molecular weight and are made up of simple units—the amino-acids—into which they are ultimately broken up during the process of digestion. The proteins are the real builders of the tissues of our body. Our hair, nails, heart and lungs are all made up of proteins. During daily work our body tissues like the bolts and nuts of a machine get worn out. In order to make good the wear and tear of the body cells, one must take in the requisite amount of proteins. Our daily requirement is about 30 gms. a day. Meat, eggs, fish and milk are the sources of animal protein, whereas pulses, peas and beans are the sources of vegetable protein. Under certain conditions, e.g., fasting when fats and carbohydrates, after being first consumed, are not available the body burns its protein reserves to get the supply of the necessary energy. This is why the muscles become weak during long fasting. However, obtaining energy by burning proteins is as foolish a proposition as obtaining heat by burning currency notes in preference to coal, since proteins are more costly than carbohydrates and fats.

VITAMINS. It has been learnt by experience that serious bodily disorders occur even when a proper supply of carbohydrates, fats, proteins, salts and water is maintained. Sailors died in thousands due to scurvy only a few centuries ago. Children living in slums developed rickety bones, and anaemic conditions (deficiency of red blood corpuscles in the body) appeared in people, in spite of all the food calories they took. It was ultimately found that these disorders were caused by the lack or deficiency of certain organic substances which were required in very small amounts in the body. These were given the names of vitamins A, B, C, D, E, K, and P.

Vitamin A found in green vegetables, cod-liver oil and butter is required for proper growth of the body. Deficiency of this vitamin results in eye diseases. Loss of resistance to disease also results from deficiency of this vitamin.

Vitamin B. Comprises about 18 vitamins. The vitamins of this group also are very important and have a profound effect on the human health. Greying of hair, pernicious anaemia, old age changes, beriberi and unhealthy skin conditions are caused by the deficiency of the members of Vitamin B group. The nutritive layer (Pericasp) of rice grains contains Vitamin B and prevents beriberi and nervous disorders. This is why people eating polished rice in which the pericasp of the rice grain is removed in the process of milling are likely to suffer from this disease. We get our Vitamin B requirements from rice polishings, milk, yeast, brownbread, yolk of egg, liver and dry beans.

Vitamin C. The sailors suffering from scurvey a few centuries ago could be cured of this disease by giving them lemon and orange juice. It is now known that citrus fruits and tomatoes contains a vitamin which has come to be called Vitamin C. It also builds healthy teeth.

Vitamin D. Butter, cod-liver oil and fats have this vitamin. Deficiency of this vitamin results in lack of nourishment for bones, which, do not grow properly. The well-known disease rickets of children dwelling in the slums when enough sunlight is not available is due to lack of this vitamin in their diet. A certain fat found in our skin is converted into Vitamin D by the action of sunlight.

Vitamin E. is found in lettuce, wheat-germ oil, green leaves and seedlings. This vitamin is responsible for the proper functioning of the reproductive system. Its deficiency causes sterility.

Vitamin K. found in leafy vegetables and spinach is necessary for the clotting of blood to prevent continuous bleeding.

Vitamin P. is found in lemon peel, green pepper and citrus juices. This vitamin also prevents haemorrhage by keeping the blood vessels in a healthy condition.

WATER is the most important constituent of human food. About 60% of the body's weight is due to water and it is because of this, that it has been said. "Even the Archbishop of Canterbury comprises 59% water". Water is the medium in which all the chemical reactions of the body take place. Since water is excreted out in flushing the metabolic waste products as sweat and urine, its supply must be constantly replenished. We can do without food for a few weeks but not without water even for a few days.

SALTS. As we all know our bones are built up of calcium and phosphorus which together form calcium phosphate. Sodium chloride or common salt is a constituent of our blood which forms about ½% of this fluid. A diet which is deficient in calcium and phosphorus will result in the weakening of bones and teeth which will loose their calcium to keep the calcium content of the blood at a steady level. We get our calcium and phosphorus from milk cheese, green vegetables, fish and meat. Iron salts are also necessary for the blood. Iodine is required in minute quantities for building up the hormone thyroxin in the thyroid glands. In some eastern districts of Uttar Pradesh, e.g., Deoria (Tehsil Padrauna) people are seen with large swellings in their necks. This disease, called goitre, is caused by deficiency of Iodine. Very minute quantities of other elements like zinc, cobalt, potassium, magnesium, copper and even arsenic are required as trace elements for maintaining proper health. A supply of these trace elements to our body is assured since almost all kinds of food, and water contain them in minute quantities.

CHAPTER TWENTY-TWO

How Food is Used in the Body

The body cannot use food directly for producing energy. As we have said, chemical reactions in the body take place in the medium of water, and there it is necessary to break food down into those components which are more readily soluble in water. Again, these various components of food (proteins consist of 24 'amino acids') are required by the human body in a proportion which is different from the proportion in which they are found in the food as we eat it. Milk protein is different from the protein of our tissues, and therefore it has to be broken down into simpler components—the amino acids—before the body can use these amino acids to build its own tissue. In scientific language the break-down of food into simpler substances is called digestion, and the absorption of these substances by the body is called assimilation.

Proteins, carbohydrates and fats can be converted into simpler substances even in the laboratories. For example, carbohydrates can be converted into the simple substance glucose, by heating them for a long time mixed with an acid. Proteins can be converted into simple 'amino acids', by heating them along with acids for long periods at temperatures of 200 to 300 degrees Centigrade. In our body, however, these reactions are carried on at a much lower temperature—i.e., about 98.4°F (36.9°C)—the body temperature. This is possible because of the presence in our body of the enzymes, which are biological catalysts. Enzymes or catalysts are agents which facilitate a change without undergoing any change themselves.[1] An interesting fact is that these biological catalysts are protein-like substances and they are produced in the various cells of the body when and where they are required.

---

[1] For example manganese dioxide (MnO_2) acts as a catalyst in the following reaction:

Potassium chlorate yields oxygen very slowly when it is heated to about 370°C. But in the presence of MnO_2 it gives up oxygen more rapidly at a temperature of only about 240°C.

Digestion

In the mouth, the food is broken up into smaller bits by the grinding action of the teeth, and a juice called saliva coming from the salivary glands reacts with it. An enzyme called ptylin in the saliva changes starch into sugar. This can be verified by chewing rice or bread for a long time and noting that it starts tasting sweet because the starch in it is converted into sugar. When food is swallowed, the contractions of the food-pipe push it down into the stomach. The contractions of the stomach further break down the food, and mix it with gastric juice which comes from the cells lining the stomach wall. Gastric juice has an enzyme which acts upon proteins in the food, changing them into simpler proteins such as peptones and proteoses.

From the stomach the food in a semi-fluid state passes into the duodenum, where bile from the liver and the pancreatic juice from the pancreas act on it. There are three enzymes in the pancreatic juice which are needed for the break-down of starch, proteins and fats. Starch is changed into glucose, proteins mostly into amino acids, and fats into fatty acids and glycerine. Bile assists the pancreatic juice in its function. From the duodenum food passes into the small intestines where digestion is completed.

Assimilation

The inside of the small intestines and also of the large intestines into which food goes next, have hair-like projections which are called *vilii*. The *vilii* have numerous small vessels, one set of them is called blood capillaries and the other lymph capillaries. When the digested food passes along some 30 ft. of the length of the small intestines, it is absorbed by the capillaries. Glucose and amino acids are taken up by blood capillaries and the fatty acids and glycerine by the lymph capillaries.

All the blood capillaries join together to form a big blood vessel, called the hepatic portal vein, which takes this blood, enriched with glucose and amino acids, into the liver. The liver acts as a filter for the assimilated food. It allows only the necessary amount to pass through it and stores the rest. Thus the excess glucose is converted into glycogen (a form of starch) and stored in the liver. This glycogen is again changed into glucose and passed into the blood as the body needs it. This way we are ensured of a regular supply of glucose—our chief energy-giving substance. In a similar way, the liver allows amino acids in the right proportion to proceed beyond it and converts the unwanted amino acids into waste products.

The lymph capillaries of the intestines also join together and pour fatty acids and glycerine directly into the blood circulation. Fatty acids and glycerine not required by the body combine again to form fat which is stored up in the tissues. This fat can also be mobilized for yielding energy when required by the body. While the fat is in position it acts as a heat insulator for the body.

Release of Energy

We can burn fats, carbohydrates and proteins in the laboratory. This burning takes place in the presence of oxygen; heat, light and other forms of energy are produced. Fats and carbohydrates on burning give out carbon dioxide and water. Proteins give out carbon dioxide, water and nitrogen. In the laboratory the process of burning is spontaneous. It takes place at a high temperature. A lot of energy is suddenly produced and therefore wasted. In the body, however, burning takes place at the body temperature which is much lower, and it is controlled in such a way that only a small amount of energy is produced at every step. Energy is therefore more effectively utilized. The controlled release of energy is possible because of the presence of enzymes. In the presence of these enzymes we are able to convert carbohydrates and fats into carbon dioxide and water (as in the laboratory); but proteins are converted into urea which itself is a compound consisting a carbon, hydrogen, oxygen and nitrogen. Energy released from a gramme of carbohydrate, fat and protein is tabulated on p. 153.

Proteins yield less energy inside the body only because they are not burnt to the same extent inside the body as outside.

Urea can be burnt outside the body to give carbon dioxide, water and nitrogen, liberating one more calorie per gramme.

Energy produced from 1 gm.	*Inside the body*	*Outside the body*
Carbohydrate	4 Cals.[1]	4 Cals.
Fat	9 ,,	9 ,,
Protein	4 ,,	5 ,,

Energy Requirement

We need a minimum of 1680 Calories of energy daily and thus a minimum of food, to keep us alive. The energy requirements of the body increase with the type of work done and they are listed below:

Absolute rest[2]	1680 Cals. daily
Rest in bed	1890 ,, ,,
Eating	2100 ,, ,,
At ease	2250 ,, ,,
Moderate work	3360 ,, ,,
Heavy work	6720 ,, ,,

In a balanced diet of an average person needing 2675 Cals., the three energy-producing foods should be in the following proportion:

Proteins	190 g	400 Cals.	15%
Carbohydrate	400 g	1600 Cals.	60%
Fats	70 g	675 Cals.	25%

Oxygen for Combustion—Respiration

The oxygen necessary for burning these energy-producing foods in the body is provided by the air we breathe in. The expansion of the chest cavity during the process of breathing air in, and contraction during breathing it out are effected by chest muscles, and the powerful muscles of the diaphragm which forms the base of the chest cavity. The air which is taken in is partly cleansed and warmed during its passage through the nose, and then it goes into the windpipe. The windpipe divides into two, one branch taking the air into each lung. These branches of the windpipe divide and subdivide in the lungs, ending in very small (microscopic) blind air sacs. These air sacs are richly lined with blood capillaries. It is here across the thin walls of the air sacs and the equally thin walls of the capillaries that the blood is able to take oxygen from the fresh air.

---

[1] The unit of energy here is a Calorie which is equal to 1000 calories. It is the energy which would raise the temperature of 1000 gm. of water by 1 C.

[2] Because even at complete rest the heart keeps beating, breathing continues and the body is kept warm.

Transport of Oxygen and Fuel, Removal of Waste Products—Blood Circulation

The fuel and oxygen which are necessary for the release of energy and therefore for the performance of work by any part of the body, are carried to that part by the blood. The waste products from every part of the body are also removed by the blood. Thus every part of the body is supplied with blood.

The heart gets the oxygen-containing blood from the lungs, pumps it through the blood vessels called the arteries to all parts of the body. In each part these arteries break up into fine capillaries. It is here that the blood gives over oxygen and food to the tissues, and takes up carbon dioxide, water, urea and other waste products. These capillaries join up again to form the veins which carry the blood back to the heart. It is possible to see how blood is able to perform this double task.

Blood is a tissue, but unlike other tissues its cells are not anchored down in one place, they are floating in a liquid called plasma. Blood cells are of three types: (i) Red cells, called the red blood corpuscles, are extremely small discs—3/10,000 cm. in diameter. In each drop of blood there are about 250-300 million red blood corpuscles. Their red colour is due to a pigment called haemoglobin. Haemoglobin is an iron compound, it combines quickly and easily both with oxygen and carbon dioxide, and it also releases them with the same ease. So when the blood flows through the lungs, haemoglobin in the red cells takes on oxygen from the air we have breathed in, and gives up carbon dioxide, brought from the various tissues, to the air. In the tissue and cells, just the reverse goes on. The cells take oxygen from the blood and pass on their carbon dioxide to it. Haemoglobin has a bright red colour when it combines with oxygen and slightly darker red colour when it combines with carbon dioxide. That explains why the blood in the arteries is lighter in colour than the blood in the veins. (ii) White cells or white blood corpuscles are colourless and irregular in shape. They are bigger than red blood corpuscles, and are much fewer in number—only 350-500 thousand in a drop of blood. These white blood corpuscles eat up the disease germs and thus defend our body against infections. (iii) Platelets are very small cells which contain a protein. In case of a cut, the platelets break down, and the protein is released. As soon as it comes in contact with air, it sets into a gel. This gel entangles the red and white blood corpuscles and thus forms a clot. Clotting stops bleeding and seals the wound from outside infection.

The plasma in which all the three kinds of cells float is a very pale liquid. It has many substances in solution for example, the common salt, glucose, amino acids, fatty acids, and urea. It is plasma which carries food to the cells and removes the waste products from them.

The composition of blood remains constant within very slight fluctuations. Even after we have drunk a lot of water, our blood does not dilute. This is mainly regulated by the kidneys. If large quantities of water are taken, kidneys remove most of it and urine becomes scanty. In addition foreign substances like alcohol are rapidly removed from the blood by the kidneys.

Cells as Chemical Factories—Metabolism

Once the cells of the body get food and oxygen, they burn the food in the presence of enzymes to produce energy. It is also in the cells that the body tissue is built from the amino acids supplied to the cells. During one process food is burnt, energy produced, and some wear and tear of the cell itself is caused. During the other process, body tissue is built up from the food supplied to the cells, thus repairing the effects of wear and tear. These two processes which are balanced in a healthy person are called metabolism.

Removal of Waste Products From the Body—Excretion

The body has also to get rid of the waste products of metabolism. Of these carbon dioxide and water, from the break down of carbohydrates and fats, are removed through the lungs in a way which has been already explained. Urea, which is formed from proteins and amino acids is mostly removed by the kidneys. The blood vessels taking the blood to the kidneys divide and subdivide into little bunches of capillaries, which are surrounded by very fine tubes called urinary tubules. This is the apparatus which filters out water along with urea and some salts from the blood in the capillaries and sends it into the tubules. Alcohol, nicotine from tobacco and other substances foreign to the body like poisons, are also filtered into the tubules. Each tubule is again surrounded by blood vessels on its passage through the kidney. Here most of the water, and some valuable salts are reabsorbed into the blood. Out of sixty quarts of urine originally secreted, fifty-nine are reabsorbed, and only one enters the bladder through the ureter. A small amount of urea is also excreted by the skin through perspiration. But the function of perspiration is not so much to get rid of the metabolic waste, as to cool the body by its evaporation. Thus on a hot day, or after exercise there is a lot of perspiration, and on a cool day, there is practically no perspiration.

Co-ordination of Functions

Different cells and organs of our body act as a connected whole, and their co-ordination is affected in two ways: by some chemicals produced in the body, and through the nervous system.

The special chemical substances which effect co-ordination in the body are called hormones. The glands which produce them are called endocrine glands or ductless glands, because unlike the liver and the pancreas which have their own ducts or tubes to carry their secretions to the places where they are required, the endocrine glands do not have any ducts and their secretions are directly poured into the blood stream when the blood circulates through them. The ductless glands make hormones from the amino acids and other chemicals supplied to them by the blood. Some hormones have only a limited effect, for example gastrin, a hormone secreted by the stomach when food enters it, makes the cells in the stomach secrete more gastric juice. Similarly other hormones cause the cells of the liver, the pancreas and the small intestines to secrete their juices. There are other hormones which affect cells over the whole body. The hormone from the thyroid regulates the rate at which metabolism goes on in the whole body. If there is more of this hormone in the blood than its normal quantity, metabolism becomes faster, the person loses weight and becomes irritable and nervous. If there is too little of this hormone in the blood, metabolism is slower and the person becomes fat and dull. Another hormone, insulin, secreted by the pancreas (in addition to the pancreatic juice) regulates the metabolism of sugar in the body. A deficiency of insulin means that the body cannot utilise sugar properly, a condition called diabetes. Other important hormones secreted by the pituitary glands regulate the growth of the body. The hormones from the sex glands together with those from the pituitary lead to the development of a child into a man or a woman. The secretion of the various hormones has to be in some definite proportion depending on the age of a person.

Nervous System

The brain, the spinal cord and the nerves connecting them with different parts of the body are responsible for making us aware of our surroundings, for co-ordinating all our movements, and for regulating the body temperature. In human beings the highly developed brain also makes man a thinking animal.

Some cells in our body respond to external influences called stimuli. These cells are called sense cells. When they are excited they send a message to the brain through the nerves which connect them with the brain and we feel the sensation. The nerves carry messages called impulses in an electrical form although they do not conduct electricity in the same way as a wire does. Their conduction is due to chemical changes which take place along a nerve. That is why nerves do not convey the impulses with the speed of electricity. Electricity is conducted at a speed of 186,000 miles per second whereas nerves conduct electric impulses at the speed of only 0.06 miles per second.

Different sense cells in the skin cause the sensations of hot or cold, pressure and pain. Thus when we touch something, we know whether it is hot or cold, soft or hard. If we cut our finger, the impulse (message) sent to the brain is registered there as pain.

The sense cells of the tongue respond to chemicals in our food. Depending on which particular taste cells are stimulated we get sensations of sweet, sour, salt, and bitter.

The sense cells of the nose respond to the chemicals in the air. When we smell a flower, the message sent by the sense cells in the nose is registered in the brain as fragrance.

The sense cells of the eyes respond to light. Light rays as they enter the eye are focussed on a screen called the retina just like the lens of a camera focuses light on the photographic plate. Different cells in the retina are sensitive to different colours such as red, green or blue. If all the three kinds of cells are excited we see white, but if only red and green sense cells are excited we see yellow. There are special cells in the retina which cannot differentiate colours from one another but are very sensitive to light. These help us to see objects in the dark.

The ear is also a very complicated organ. The ear-drum starts vibrating like any other drum when sound waves strike it. This sets a chain of three little bones into vibration, and their vibrations in turn start still more vibrations in the fluid filling the inner ear. The sense cells in the inner ear get stimulated by these vibrations, and send impulses to the brain, which are registered as sound. The intensity of sensation in each of the above cases depends on the number of sense cells which get stimulated.

In the inner ear there are three little tubes called the semicircular canals, which are filled with a liquid, and which have tiny sacks with *stones*, in them. One of the canals is horizontal, the other vertical and the third one slants across the other two. When the human body is bent, the *stones* in the fluid roll over and this movement stimulates sense cells in the semicircular canals,—the impulses which they send to the brain give the sensation of position, of lying down, of standing upright or of leaning over.

There are nerve impulses which carry orders from the brain to the various organs and cells in the body. These make us do things. For example, orders from the brain may cause contractions of muscles in the legs, the back, and the arms in such a co-ordinated way that we perform the act of running or walking.

The heart muscles which pumps the blood, the chest muscles and the diaphragm which contract during breathing, do not need any impulses from the brain for their normal functioning. This may be observed quite clearly in the case of a frog whose brain is removed but whose heart continues to beat. However, the impulses from the brain may modify the rate of movement even in case of such muscles, for example when someone is 'afraid' the heart beats become faster and breathing becomes more rapid.

The muscles of the food pipe, or intestines which push the food along by their contractions are not governed by any impulses from the brain, they respond to the object put in them and push it along.

Actions like the movement of the arm or the leg, which are under the deliberate control of the brain are called voluntary, while movements like the contractions of the heart muscles which are not under the deliberate control of the brain are called involuntary.

When something very hot is touched, the hand is drawn back immediately even before there is time to think about it. The heat of the object starts an impulse in the pain nerves of the hand. This impulse goes up to the spinal cord, where it is received by a 'local nerve centre' which sends an instruction along another nerve for the arm to withdraw. All this happens within a split second. The feeling of pain, however, is not caused by the spinal cord. The spinal cord sends a message to the brain where the actual sensation of the pain is felt and perhaps one thinks of applying some ointment to the burn. Actions which take place under a stimulus, under the orders of the spinal cord only, are called reflex actions.

Control of Body Temperature

The temperature of the human body is maintained at the normal level of about 98.4°F (36.9°C). This is the most suitable temperature for the chemical actions going on in the human body. We feel uncomfortable when the body temperature rises by even half a degree as in fever; and we feel very weak and cold if the temperature is lower than the normal. The body temperature is controlled by temperature centres in the brain. When a lot of heat is produced in the body, as during exercise, the blood flow to the skin is increased, more sweat is secreted by the sweat glands in the skin and this by evaporation cools the body. On a cold day, when the body loses too much heat, and there is a danger that the body temperature would fall, we start shivering. The muscles start contracting and relaxing automatically to produce heat. In a sunstroke when the temperature centre is damaged by the hot rays of the sun falling directly on it, the body temperature may rise upto 110°F and a person may die unless something is done to cool the body artificially.

Man, the Thinking Animal

Other animals eat food, grow and respond to their environments, but they have to take life as they find it. Of all the living beings man alone is able to change his environment. He wears clothes to keep himself warm, builds houses to shelter him from the heat of summer and from cold in winter, makes trains and aeroplanes to move from place to place faster than his legs can carry him. Man is able to do all this because his brain is more highly developed than the brains of other animals. This is especially true of the front part of the brain called the cerebrum. It is in the cerebrum that we feel, learn and think.

Reproduction

It has already been said that the cells of the body undergo constant division. That is how new cells are formed. A skin cell divides to produce two skin cells; a white blood corpuscle divides to form two white blood corpuscles. But when an egg cell produced in the female organs called the ovaries, and a sperm cell produced by the male organs called the testes unite, the cell formed by their union divides into two cells and these keep on dividing into more and different cells. In this way the different kinds of cells we have in our bodies are formed. The special nature of the egg cell and the sperm cell, namely that they alone out of millions of cells are capable of growing into all kinds of cells which go to make a new individual in the mother's body, requires explanation.

It has been pointed out that the nucleus of each of the cells in our body has 46 chromosomes in it, and that these exist in pairs. The egg cell and the sperm cell have only 23 chromosomes each. Thus it is necessary for the birth of a new person, that not only the egg and the sperm cells be formed in the bodies of the female and the male but also that they should come together and unite to restore the full number of 46 chromosomes in the zygote. The mother's womb provides the place where a baby can grow from a single cell formed by the union of the egg and sperm cell (zygote). All the egg cells have a chromosome called the X-chromosome, but only half of the sperm cells have the X-chromosome, the other half have much smaller Y-chromosomes. It is these X and Y chromosomes in the sperm cell which determine whether the baby will be a boy or a girl.

From the mother		From the father	
X	+	X	—— XX (girl)
X	+	Y	—— XY (boy)

Although the sex of the baby is determined at conception, the external features of the embryo becomes differentiated only after about six weeks.

Babies are not only boys or girls but they are also either fair or dark: blue-eyed or brown-eyed: they may grow eventually very tall or remain short. It is the genes in the chromosomes which determines these characteristics. Chromosomes are strings of genes. Children get half of their genes from the 24 chromosomes of the sperm cell from their father and the other half from the 24 chromosomes from their mother. That is why children usually look like their parents or their grandparents. On the average, girls start changing into adult women between nine and thirteen and boys between eleven and fifteen. These are the years of adolescence, the period when one is not a child any more, but has not yet grown quite into an adult.

Mentally and physically a lot of changes take place in the body at this time. These changes are brought about by the hormones of the pituitary and sex glands (ovaries in girls and testes in boys). Young people at this age feel tired and sleepy because their bodies grow very fast and use up energy very quickly. They are awkward and clumsy, their complexion often loses colour. All these are temporary effects and soon disappear after the person has become an adult.

The sexual organs which had no part until now in a child's life, suddenly develop and start functioning during adolescence. This often causes much worry and anxiety to a young person. It is best to try to understand rationally what changes are taking place in the adolescent. Adolescents should be encouraged to acquire the knowledge of correct facts about sex from books written by experts and from their parents or a doctor instead of getting incorrect ideas from those who themselves are ill informed. There is nothing wrong or secret about the sex organs, it is because of them that the human race has survived.

CHAPTER TWENTY-THREE

Health and Disease

A body is healthy if all its organs function in the normal way. Any deviation from this is a state of disease. Diseases are of various types.

Diseases Due to Hormonal Unbalance

It has already been said that co-ordination between the various processes going on in the body is maintained by hormones secreted by the endocrine glands. These hormones of various types have to be secreted in correct proportion. If this proportion is upset, if there is too much or too little of a particular hormone, some abnormal symptoms will appear. We have already seen how the deficiency of insulin (from pancreas) in the body leads to diabetes, a condition in which the body cannot utilise its sugar properly: and how the deficiency of the thyroid hormone makes the rate of metabolism slow, i.e., the individual is mentally and physically very slow and in extreme cases may remain mentally underdeveloped.

When the disease is due to the deficiency of a certain hormone it can often be remedied by the administration of the right hormone. When, on the other hand, it is due to the over activity of a hormone-producing gland, it may become necessary to remove a part of the overdeveloped or overactive gland by means of a surgical operation.

Diseases Due to Malnutrition

Some deficiencies in our diet also lead to abnormalities. Thus if there is too little iodine or no iodine in the diet, the thyroid glands cannot produce their hormone, with the results we have seen above. If the diet lacks in iron the red blood corpuscles will not have enough haemoglobin. Such red blood corpuscles will not supply oxygen to the body in adequate quantity and the individual will grow pale and anaemic. Deficiency of vitamins in the food leads to a number of diseases. We may eat enough to fill our stomachs, but if the diet is lacking in an essential constituent, the body will suffer from a sort of hidden starvation, this is called malnutrition. Malnutrition is mainly the result of poverty, because poor people cannot afford to buy and eat in adequate quantity milk, meat, eggs and fruit which are necessary constituents of a balanced diet. Amongst those who are not poor, malnutrition is often due to defective choice of food or to the adoption of methods of cooking which destroy certain essential ingredients like vitamins, or render others indigestible.

The diseases which are due to a deficiency of certain essential substances in food are called deficiency diseases; they can be remedied if the body is supplied with a sufficient quantity of these substances.

Diseases Due to Foreign Bodies

Certain other diseases are due to the presence of foreign substances in our body. These foreign substances may be organic in nature like the disease germs, or they may be inorganic like powdered stone from freshly ground millstone, or lead salts from paints.

Disease germ is a common term for a variety of organisms. Firstly there are the Bacteria which are small single-celled plants. Germs responsible for cholera, typhoid and tuberculosis are all different forms of bacteria. Then there are the protozoa which are small single-celled animals. The germs which cause amoebic dysentery belongs to this class. In addition there are also multicelluar animals like the various worms which get into the intestines or multicellular plants like the fungi which give rise to the athlete's foot and other diseases. Next come viruses which are small specks of protein, and they cause common cold, influenza, measles, etc. Disease germs multiply very rapidly once they are inside the body. They invade and destroy tissues directly, or produce toxins which have very harmful effects.

Certain inorganic substances have also a harmful effect on the body. Stone-dust when inhaled in large quantities by workers at stone-grinding machines cause a lung disease called silicosis. Compounds of lead cause lead poisoning in workers in the paint industry. Workers in the match industry similarly suffer from the harmful effects of phosphorous. These are called occupational diseases, and can be prevented to a large extent by taking precautions against workers getting large quantities of the harmful substance into their bodies.

The Defence System of the Human Body

The human body has a very efficient defence system to fight invasions by foreign organic agents. We feel ill as a result of infection only when the body defences break down. The body defence works in a number of ways. The skin forms a protective lining all over the body. Disease germs cannot penetrate the skin if it is intact. The inner cavities of the body like the alimentary canal, the nose and the windpipe are lined with a pink mucous membrane. This membrane secretes a slimy substance called mucus, which entraps and kills disease germs. The hair in the nostrils also catch the dust particles laden with germs which, if not kept out, would get into our lungs with the air we breathe in. The cells lining the windpipe, and its branches have fine hair like processes called the cilia. These keep moving steadily in the upward direction, and any germs or particles which get into the windpipe are pushed upwards by their movement, until they are ejected by the reflex action of coughing. The acid in the gastric juice serves to kill some germs swallowed with food or water. The wax in the ears entraps foreign substances. The eyes are constantly washed by the disinfecting fluid from the tear glands.

If germs manage to get into the body inspite of these barriers, another type of defence mechanism comes into action. The blood vessels carrying blood to the infected area dilate, resulting in increased blood supply to that region. This causes swelling and redness in the infected part. With the plasma which oozes out of the thin walls of blood capillaries, white blood corpuscles also come out. These surround and literally eat up the germs. They are, therefore, called the phagocytes—i.e., cells which eat. The chemicals produced by the germs also stimulate the white blood corpuscles to grow and divide quicker than usual, that is why the number of white blood corpuscles usually is higher than normal in the blood of persons suffering from infectious diseases. The fluid that oozes out of the blood capillaries along with white blood corpuscles does not get back into the blood capillaries. After delivering its food to the surrounding tissue, this liquid now called lymph passes into small vessels which start in the tissues. These small vessels form bigger vessels called the lymph vessels. The lymph vessels join together and pour their contents into blood circulation near the heart. Along the lymph vessels at certain places such as the arm-pit or the neck, special glands called the lymph glands are present. New white blood corpuscles are made in the lymph glands, and the ones which have died in their fight against disease germs are destroyed. The lymph glands also check and destroy the poisons produced by the disease germs. The lymph glands near a seat of infection often become swollen and tender. If there is a boil on the lymph gland in the arm-pit it becomes a tender painful swelling.

Some red cells are also destroyed by disease germs. Germs responsible for malaria largely attack the red blood corpuscles. Liver and spleen remove the dead red blood corpuscles from the blood. No wonder in malaria, when a lot of these red corpuscles die, the liver and the spleen get enlarged. New red blood corpuscles are formed in the bone-marrow, as well as in the liver.

The body also reacts chemically to foreign proteins like viruses or those produced by bacteria when they get into the blood. These foreign proteins are called antigens. As a reaction to the foreign protein—a chemical is produced in the body which reacts in different ways, (*a*) it may stimulate the growth of white blood corpuscles thus strengthening body defences, (*b*) it may retard or restrict the growth of disease germs, so that they do not increase in number. The infection thus gets localised and the white blood corpuscles are better able to cope with it, (*c*) it may itself combine with the poison produced by the foreign body and thus render it harmless. This protective chemical produced by the body is called an 'antibody'. It is usually effective only against the agent which caused its formation in the first place.

Immunity

The presence of antibodies in the blood makes a person better able to fight a particular infection. This is called immunity, or safety from disease. Some antibodies like those of small-pox are effective throughout life. A person who has had small-pox once is not likely to have it again. The antibodies of cold and influenza on the other hand continue to exist only for a short period.

Pasteur was the first man to discover that antibodies could be produced artificially by introducing into the body disease germs which have been rendered harmless. This forms the basis of vaccination against small-pox, cholera and typhoid, etc.

Sometimes antibodies are produced in another animal, for example a horse or a guinea pig, and then these ready-made antibodies are introduced into the human body for protecting it against a particular disease. Immunity which is acquired in this way is not as complete as when the antibodies are produced in the human body itself.

If the immunity developed by, or induced into the body is not sufficient, the body defences may break down and the person may get the disease. In this case the fight against the disease is carried on by the administration of medicines. These substances have to be such that they may be harmful only to disease germs but harmless to the body. For example, it has been known for a long time that quinine is effective against malaria. It has been recently discovered that a group of chemicals called the sulpha drugs are helpful in preventing the infection of wounds and in fighting infections which have already penetrated into the body. Penicillin and some other related compounds like streptomycin and aureomycin are produced and they have proved very effective against bacterial infections.

Modern medical science can also help us in preventing disease. Some of the disease germs, for example those of malaria, cholera and typhoid, etc., are carried by mosquitoes, flies and food. Methods have been devised (like the use of D.D.T. disinfectant) for the destruction of the agents causing diseases, and for the disinfection of food. It is because of the success of these measures that in the advanced countries of the world diseases due to germs have practically disappeared. In consequence the average duration of life has greatly increased and now people commonly die only of organic diseases such as a defective heart, hardening of arteries or cancer, etc. A considerable amount of medical research is going on to find the causes of and cures for such diseases and there is no doubt that in future these diseases will also be conquered.

Medical science has made great advances in surgery and sometimes when a disease cannot be cured by means of medicines an operation may save the life of the patient. In recent years the techniques of operation have developed to such an extent that surgery of the brain and even of the heart has become possible.

The Health of the People

The problem of improving the health of the people as a whole is very important because apart from humanitarian considerations, the working ability of the people depends on the state of their health. In a country where people are disease-ridden, and where malnutrition is common, hard work and economic advancement become exceedingly difficult, almost impossible. That is why in Great Britain there is a national health service which provides for every citizen effective medical treatment on payment of a very small sum of money. That is why in socialist countries such as the USSR, medical service is completely free.

In our country India which is poor and where people cannot afford a balanced diet, and where due to lack of education, sanitation needs to be improved, a campaign for cleanliness and destruction of germ-carrying parasites has to be carried on, competent medical advice made available for all, reliable medicines have to be prepared, and widespread medical education and training have to be undertaken. A carefully drawn up and comprehensive plan can save millions of lives every year and help in the advancement of the economy of our country. Only a planned attack on this vast problem can lead to human welfare.

ILLUSTRATIONS

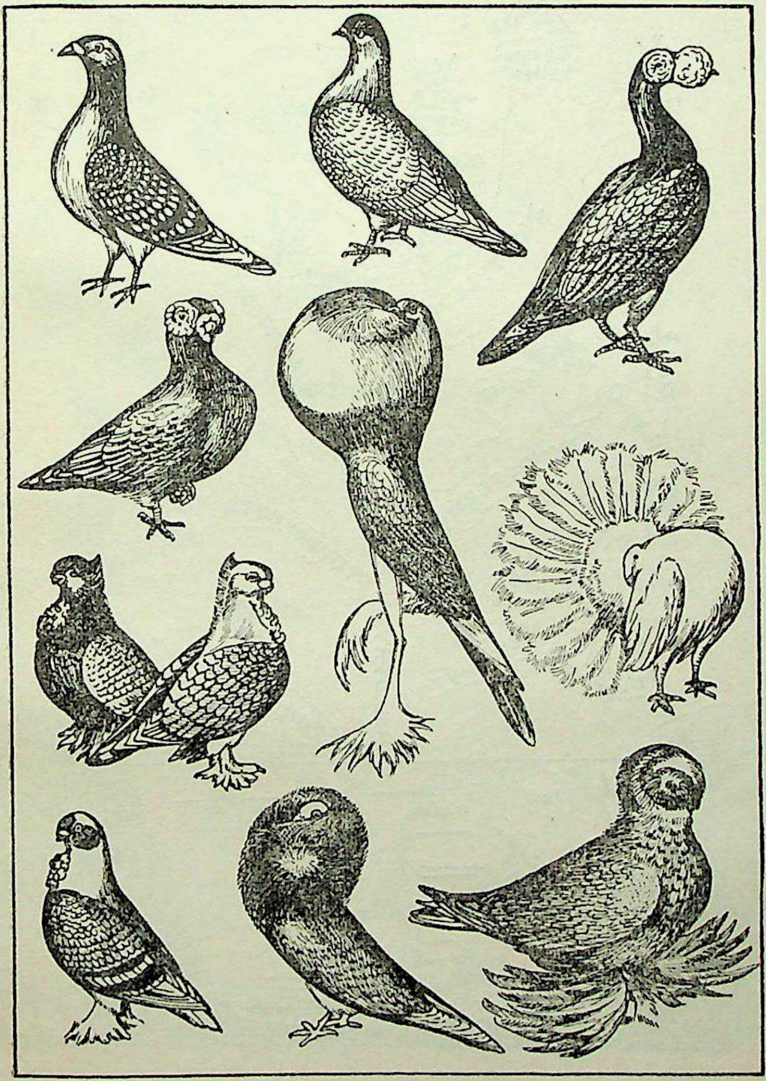


FIGURE 1
Some Varieties of One "kind" of Animal, the Pigeon.
(From C. M. Beadnell, *A Picture Book of Evolution*,
Watts & Co., London). [See p. 11].

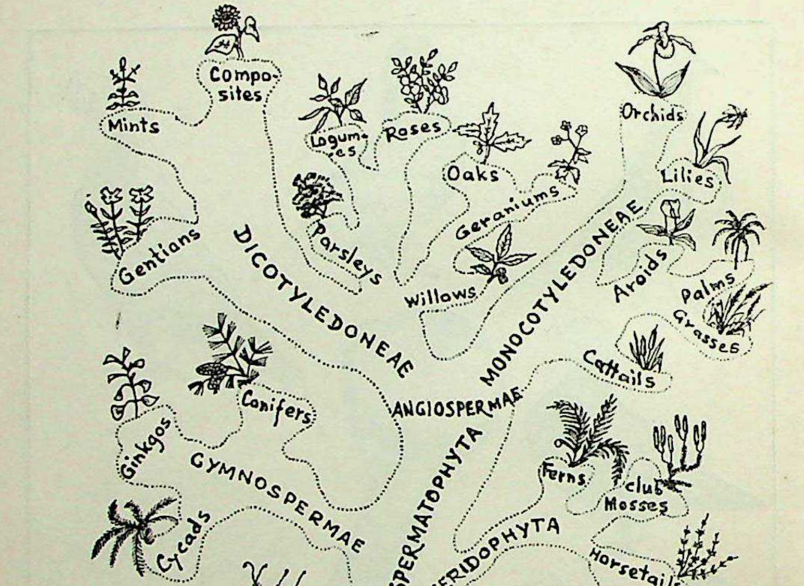

Mints
Composites
Legumes
Roses
Orchids
Lilies
Oaks
Geraniums
Gentians
Parsleys
DICOTYLEDONEAE
Willows
MONOCOTYLEDONEAE
Aroids
Palms
Grasses
Cattails
Conifers
ANGIOSPERMAE
Ginkgos
GYMNOSPERMAE
SPERMATOPHYTA
Ferns
club Mosses
Cycads
PTERIDOPHYTA
Horsetails
Mosses
BRYOPHYTA
Liver worts
THALLOPHYTA
Aseus Fungi
Basidia Fungi
FUNGI
Algal Fungi
Red
Green
ALGAE
Brown
BACTERIA

FIGURE 2
Variety in the Plant Kingdom
(From J. W. Mavor, *General Biology*, The Macmillan Co., New York). [See p. 13].

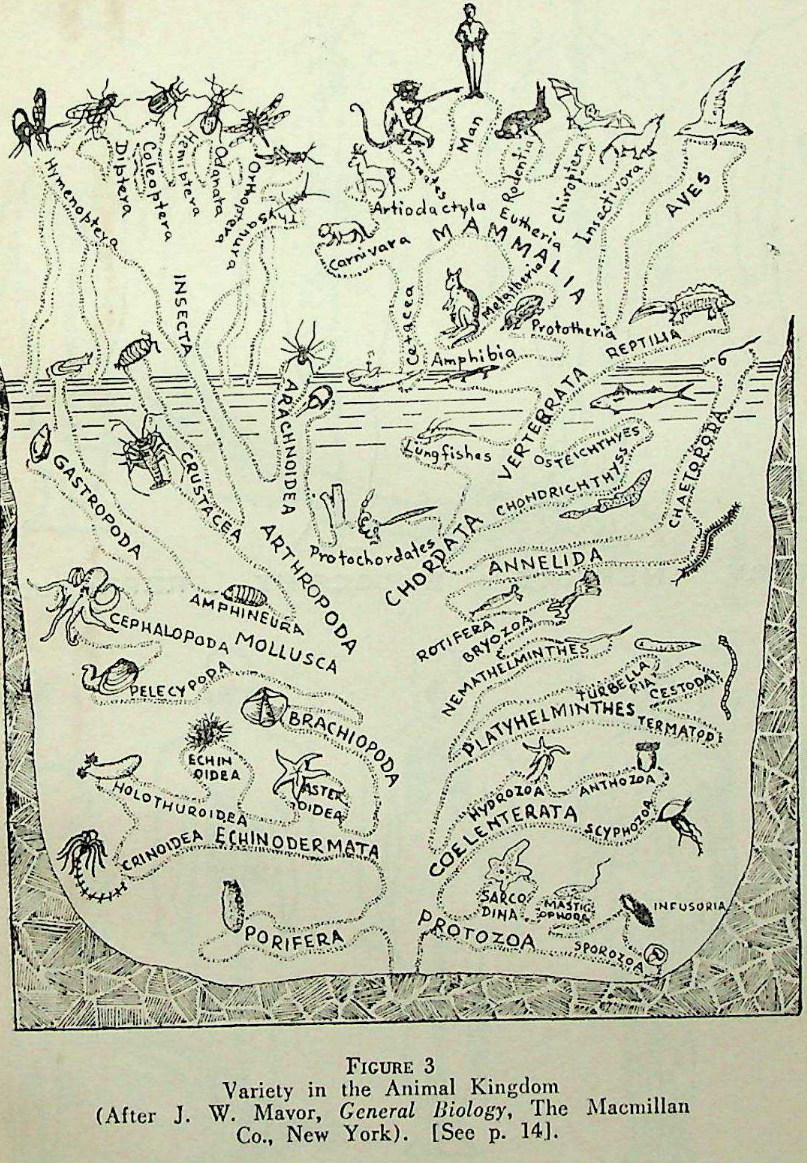

Hymenoptera
Diptera
Coleoptera
Hemiptera
Odonata
Orthoptera
Thysanura
INSECTA
Man
Primates
Rodentia
Chiroptera
Insectivora
AVES
Artiodactyla
Eutheria
Carnivara
MAMMALIA
Metatheria
Prototheria
Cetacea
Amphibia
REPTILIA
VERTEBRATA
Lungfishes
OSTEICHTHYES
CHONDRICHTHYS
CHAETOPODA
ARACHNOIDEA
CRUSTACEA
GASTROPODA
ARTHROPODA
Protochordates
CHORDATA
ANNELIDA
AMPHINEURA
CEPHALOPODA
MOLLUSCA
ROTIFERA
BRYOZOA
NEMATHELMINTHES
PELECYPODA
BRACHIOPODA
TURBELLARIA
CESTODA
PLATYHELMINTHES
TERMATODA
ECHINOIDEA
ASTEROIDEA
HOLOTHUROIDEA
HYDROZOA
ANTHOZOA
COELENTERATA
SCYPHOZOA
CRINOIDEA
ECHINODERMATA
SARCODINA
MASTIGOPHORA
INFUSORIA
PORIFERA
PROTOZOA
SPOROZOA

FIGURE 3
Variety in the Animal Kingdom
(After J. W. Mavor, *General Biology*, The Macmillan Co., New York). [See p. 14].

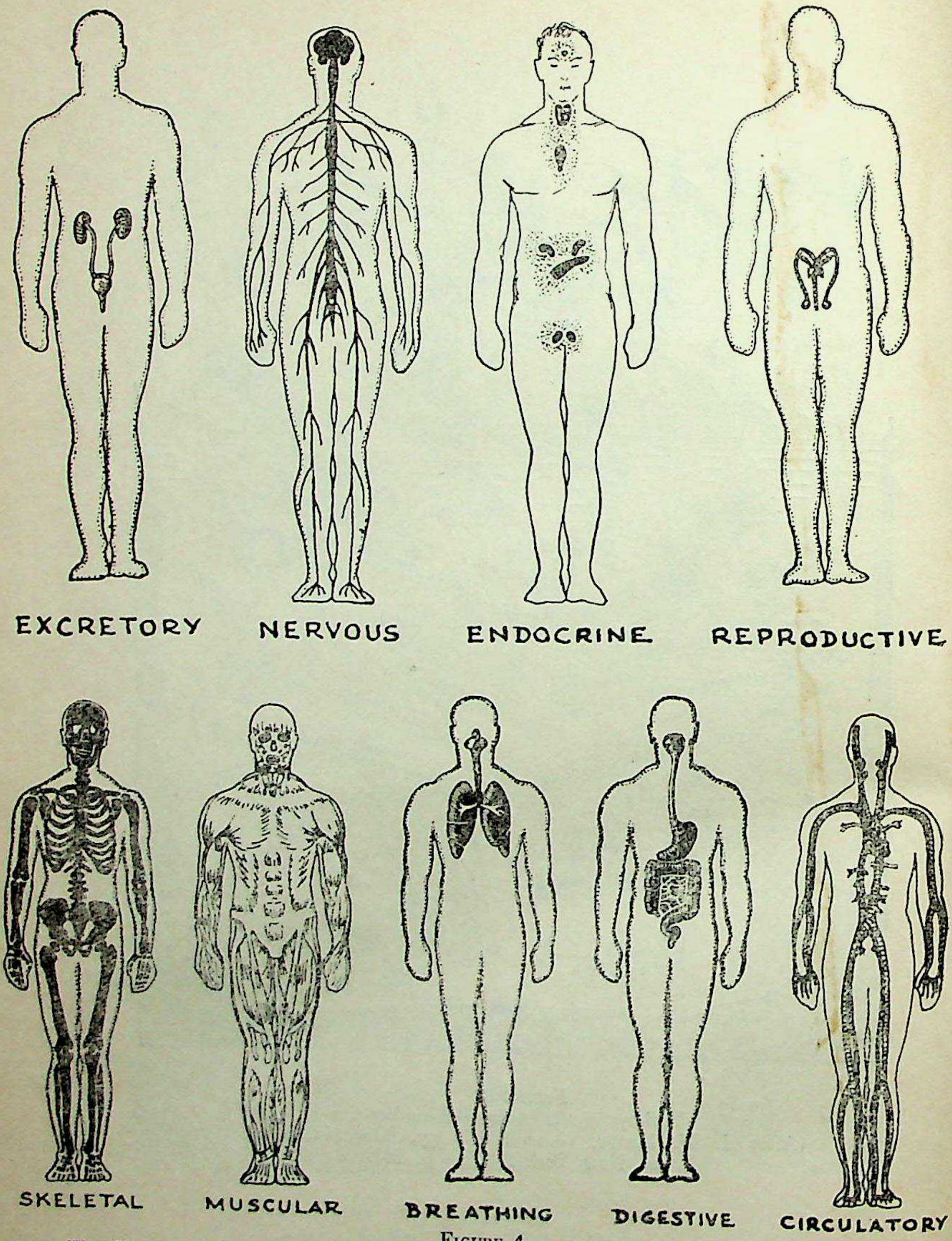

EXCRETORY
NERVOUS
ENDOCRINE
REPRODUCTIVE
SKELETAL
MUSCULAR
BREATHING
DIGESTIVE
CIRCULATORY

FIGURE 4

The Various Organ Systems that Contribute to Organization in the Human Body. (From G. Hardin, *Biology—Its Human Implications*, W. H. Freeman & Co., San Francisco, California). [See p. 19].

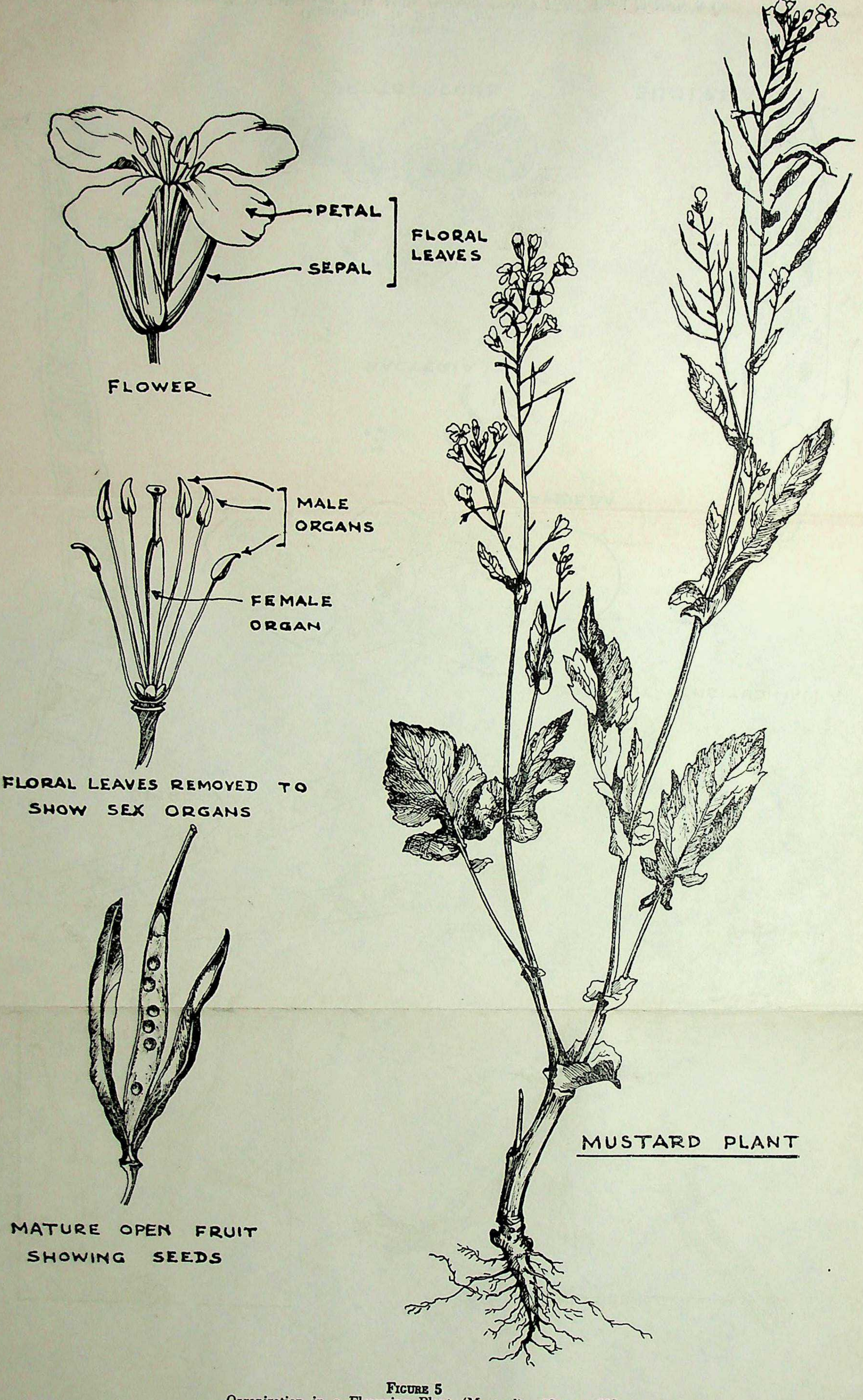

PETAL
SEPAL
FLORAL LEAVES
FLOWER
MALE ORGANS
FEMALE ORGAN
FLORAL LEAVES REMOVED TO SHOW SEX ORGANS
MATURE OPEN FRUIT SHOWING SEEDS
MUSTARD PLANT

FIGURE 5
Organization in a Flowering Plant (Mustard). [See p. 23].

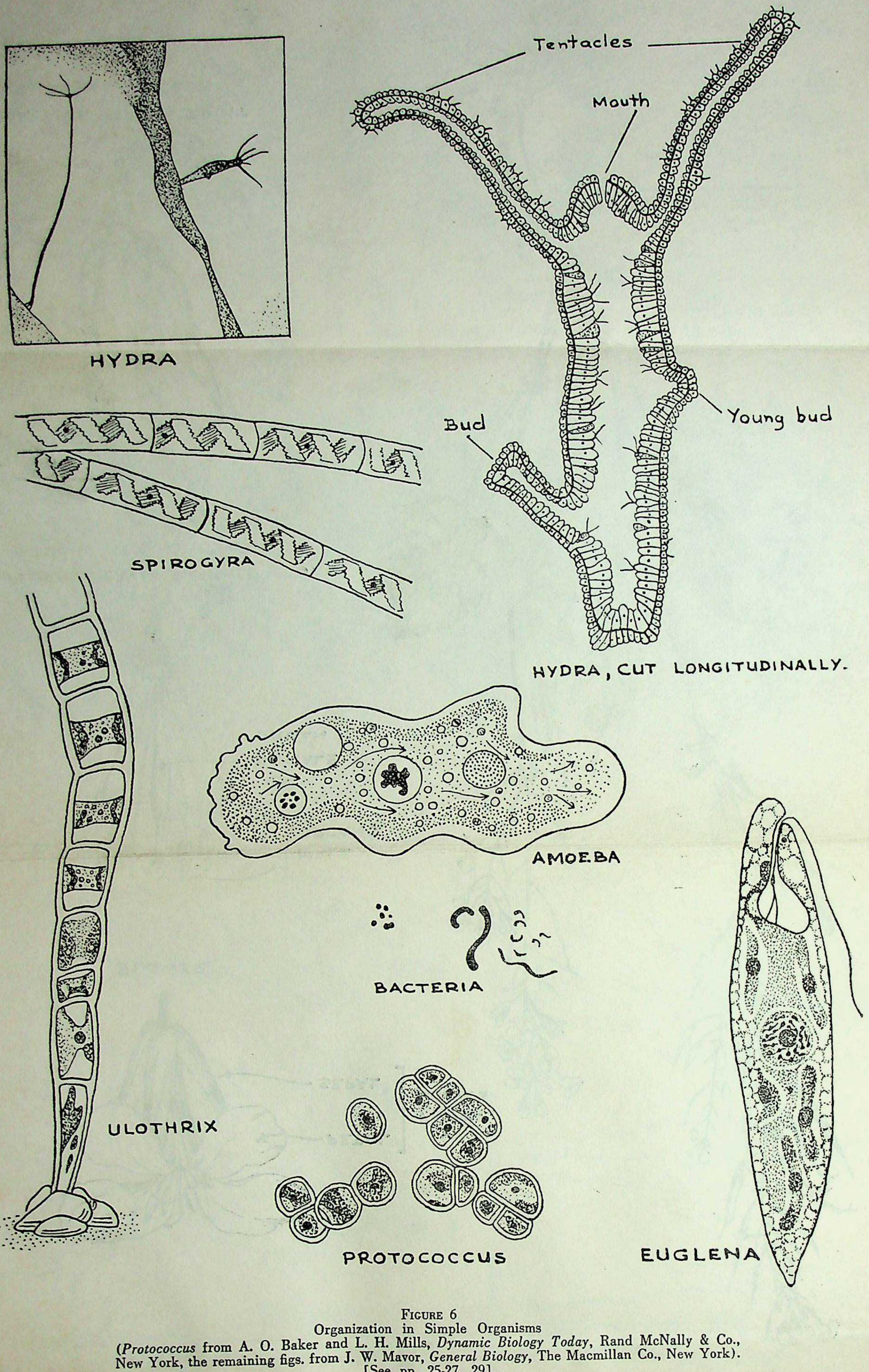

Tentacles
Mouth
HYDRA
Young bud
Bud
SPIROGYRA
HYDRA, CUT LONGITUDINALLY.
AMOEBA
BACTERIA
ULOTHRIX
PROTOCOCCUS
EUGLENA

FIGURE 6
Organization in Simple Organisms
(*Protococcus* from A. O. Baker and L. H. Mills, *Dynamic Biology Today*, Rand McNally & Co., New York, the remaining figs. from J. W. Mavor, *General Biology*, The Macmillan Co., New York).
[See pp. 25-27, 29].

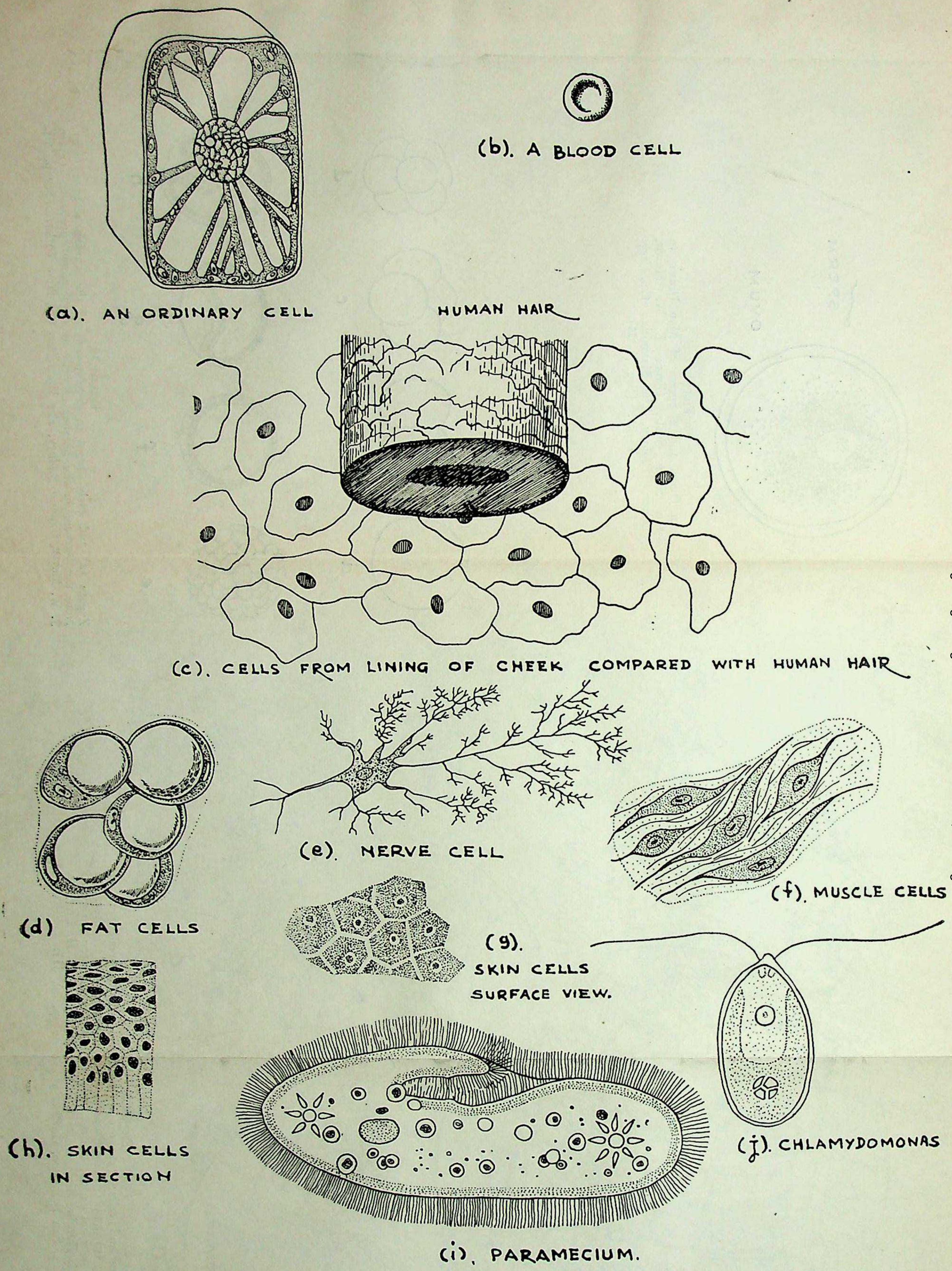

(a). AN ORDINARY CELL
(b). A BLOOD CELL
HUMAN HAIR
(c). CELLS FROM LINING OF CHEEK COMPARED WITH HUMAN HAIR
(d) FAT CELLS
(e). NERVE CELL
(f). MUSCLE CELLS
(g). SKIN CELLS SURFACE VIEW.
(h). SKIN CELLS IN SECTION
(i). PARAMECIUM.
(j). CHLAMYDOMONAS

FIGURE 7

Cells of Various Kinds: (a) an ordinary cell; (b) a blood cell; (c) cells from lining of cheek compared with human hair; (d) fat cells; (e) nerve cell; (f) muscle cells; (g) skin cells, surface view; (h) skin cells, in section; (i) *Paramecium*; (j) *Chlamydomonas*. (a) & (d) to (i) from A. O. Baker & L. H. Mills, *Dynamic Biology Today*, Rand McNally & Co., New York; (b) and (c) from G. Hardin, *Biology—Its Human Implications*, W. H. Freeman & Co., San Francisco, California; (j) from J. W. Mavor, *General Biology*, The Macmillan Co., New York. [See pp. 28-30].

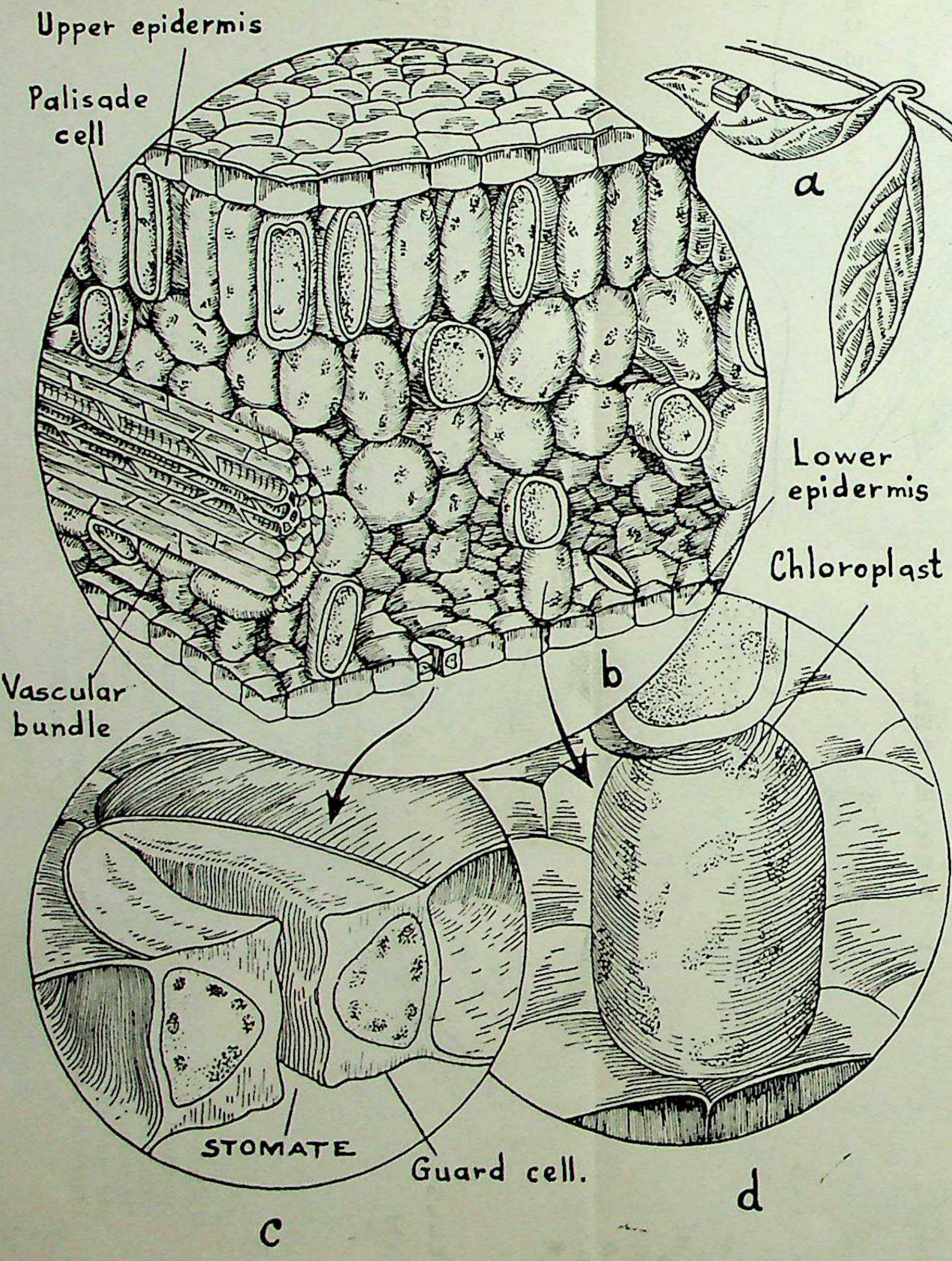

Upper epidermis
Palisade cell
a
Lower epidermis
Chloroplast
Vascular bundle
b
STOMATE
Guard cell.
c
d

FIGURE 8
Leaf, its tissues and cells; (a) two entire leaves; (b) a small part of (a) magnified; (c) and (d) small parts from (b) magnified further. In (b) & (c) is a pore cut across; the two cells surrounding the pore are guard cells. (From G. Hardin, *Biology—Its Human Implications*, W. H. Freeman & Co., San Francisco, California). [See pp. 30, 31].

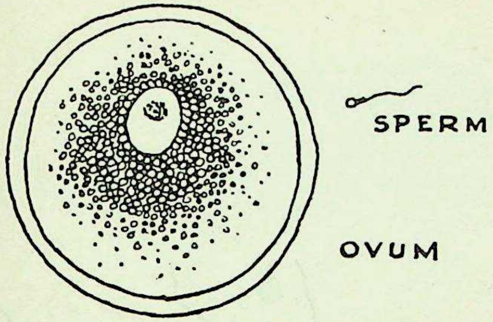


FIGURE 9
An Ovum and a Sperm of Man Drawn to the Same Scale. (From J. W. Mavor, *General Biology*, The Macmillan Co., New York). [See p. 34].

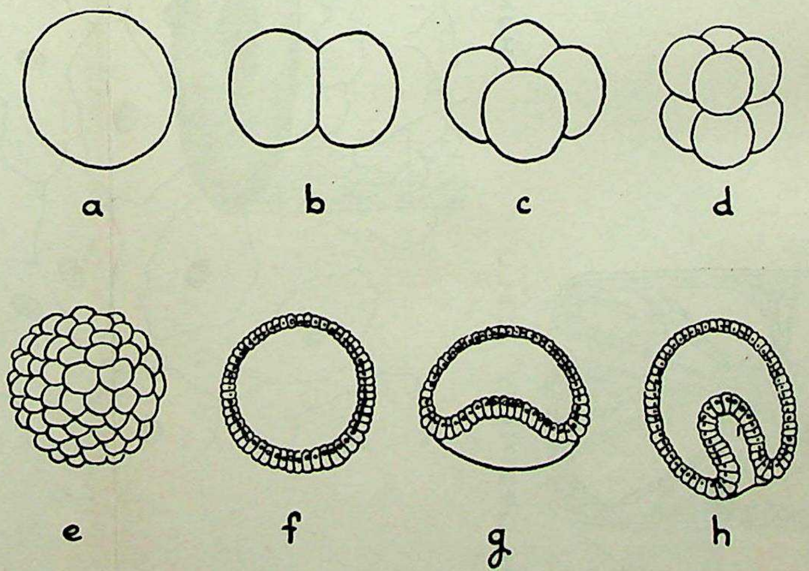


FIGURE 10
Zygote (a) and early stages in development of the starfish embryo (b-h). Note the increase in the number of cells as development proceeds. (From J. W. Mavor, *General Biology*, The Macmillan Co., New York). [See p. 35].

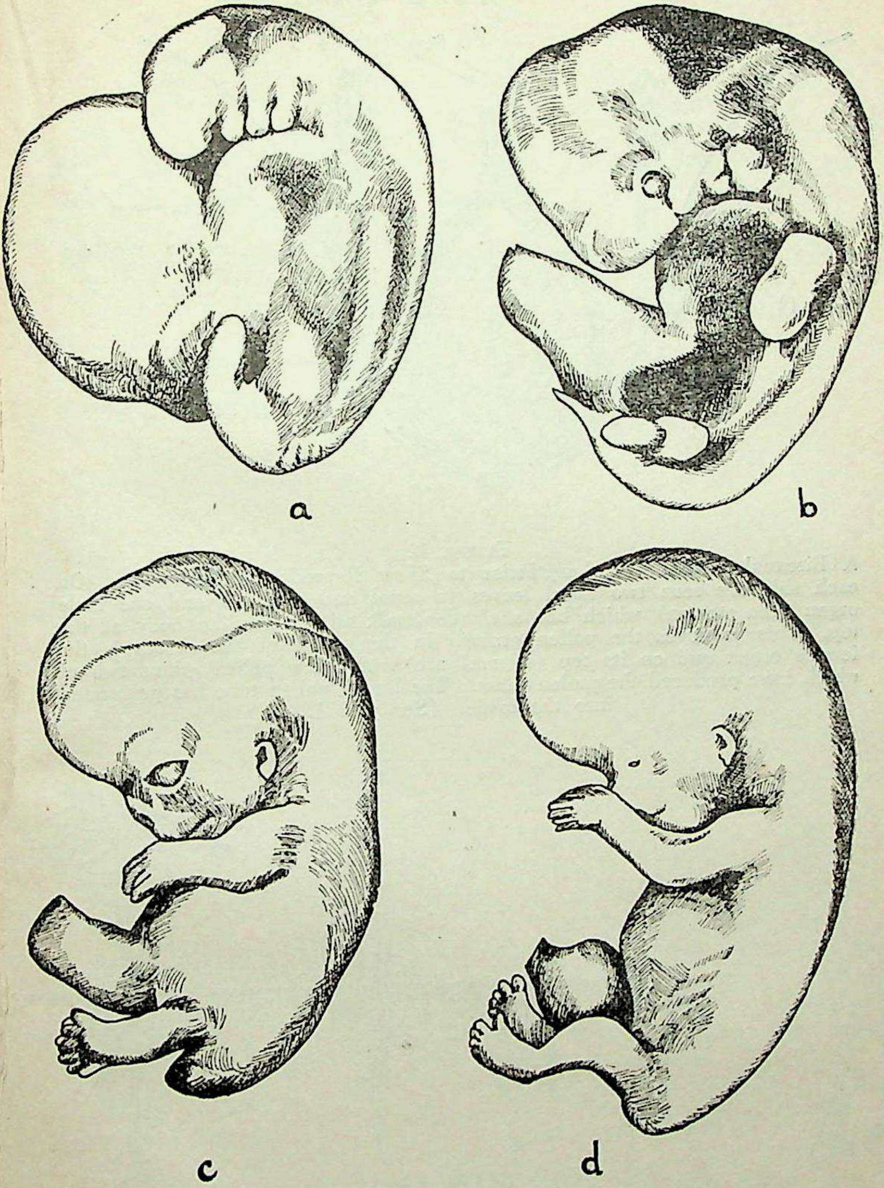


FIGURE 11
Some Stages in the Development of Human Embryo: (a) about 4 weeks old; (b) about 5 weeks old; (c) about 6 weeks old; (d) about 8 weeks old. (From G. Hardin, *Biology—Its Human Implications*, W. H. Freeman & Co. San Francisco, California). [See p. 35].

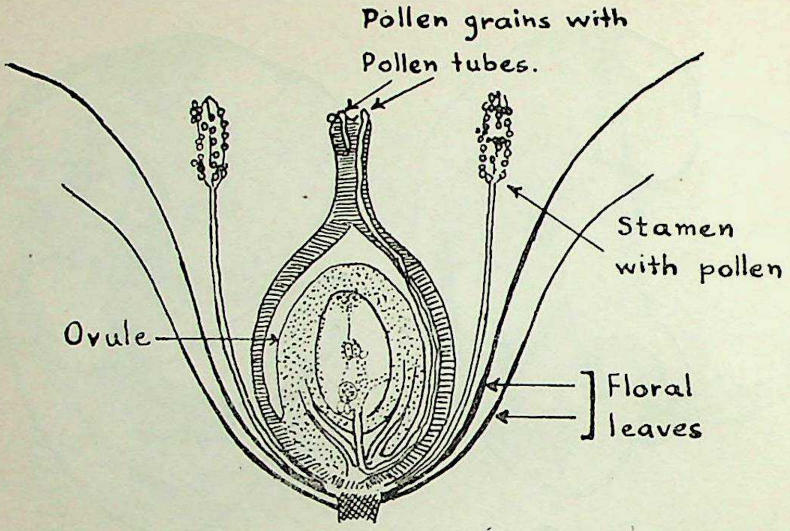

Pollen grains with
Pollen tubes.
Stamen
with pollen
Ovule
Floral
leaves

FIGURE 12
A Bisexual Flower Cut Lengthwise to Show Reproductive Structures. On each side are seen two floral leaves (a sepal and a petal) and one male organ (the stamen) which has a slender stalk with a swollen body at the top. This produces the pollen grains. In the centre of the sketch is the female organ and on its top (stigma) are seen a few pollen grains two of which have produced the pollen tubes. The longer pollen tube has penetrated into the ovule. [See p. 35].

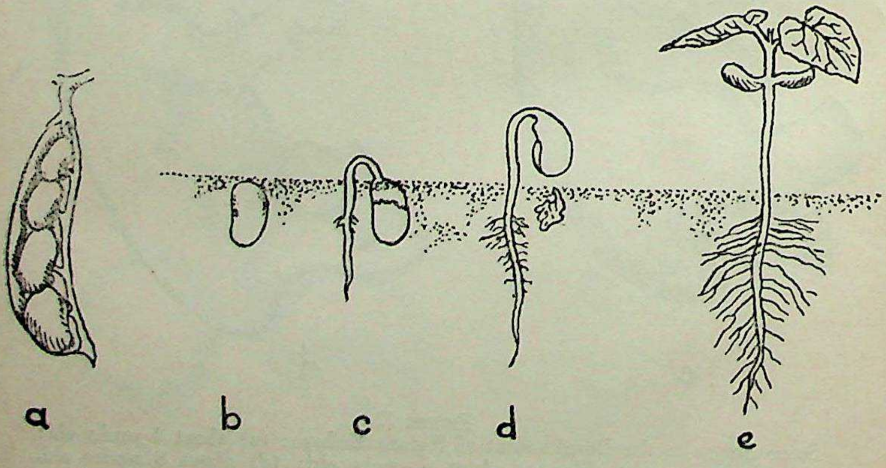


FIGURE 13
(a) A bean pod with seeds; (b-d) Seed and the stages in its germinations; (e) young seedling. (From A. O. Baker and L. H. Mills, *Dynamic Biology Today*. Rand McNally & Co., New York). [See p. 35].

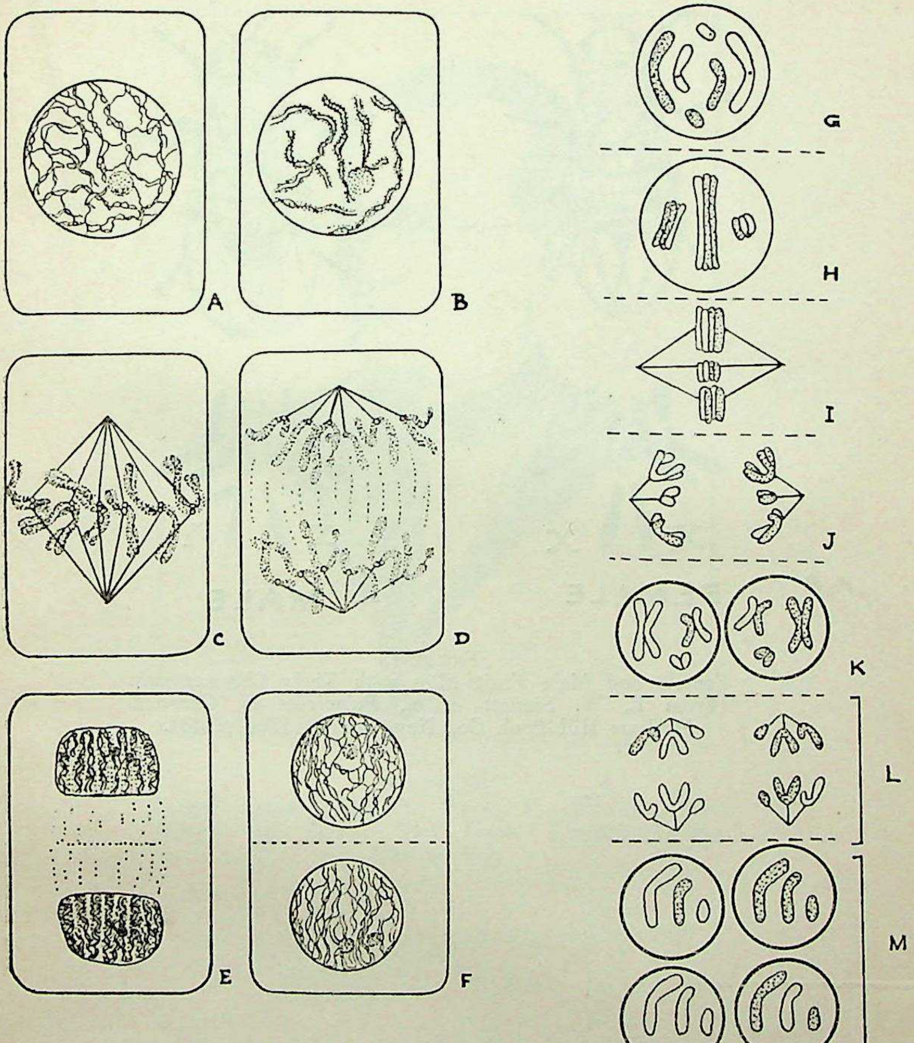


FIGURE 14
Cell Division. (a) to (f) Division in an ordinary body cell. (g) to (m) Reduction division. For explanation, see text. (From L. W. Sharp, *Fundamentals of Cytology*, McGraw Hill Book Co., New York). [See pp. 37, 38].

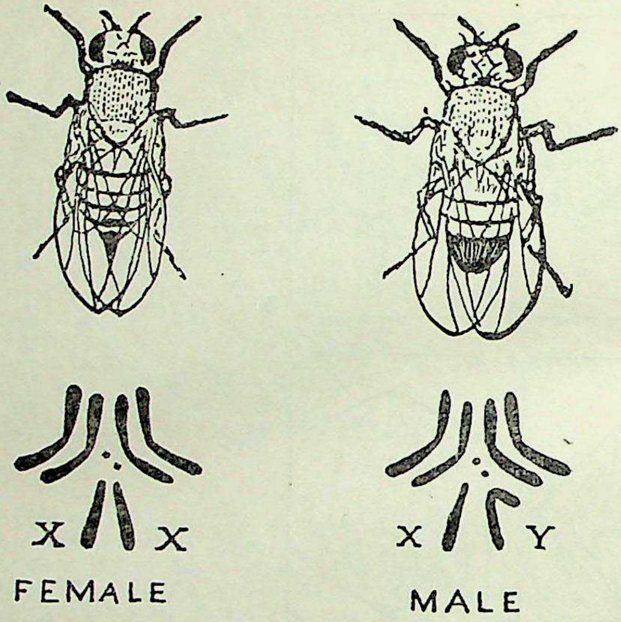

X
X
FEMALE
X
Y
MALE

FIGURE 15
Female and Male Fruit Flies with Their Chromosomes. (From E. W. Sinnott *et al*, *Principles of Genetics*. McGraw Hill Book Co., New York). [See p. 43].

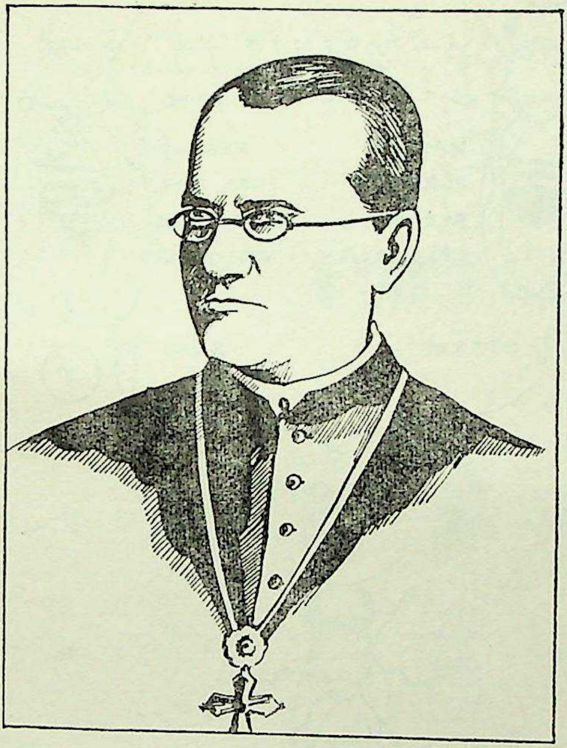


FIGURE 16
Gregor Johann Mendel (From H. Wheeler, *The Miracle of Life*. The Home Library Club). [See p. 45].

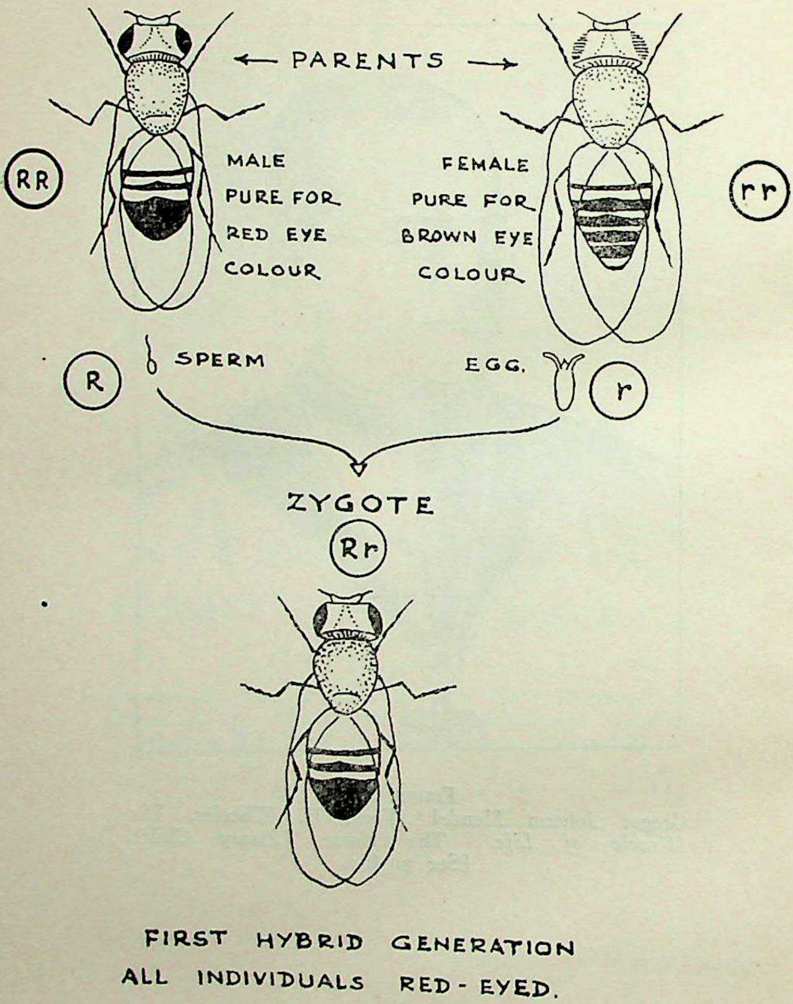

PARENTS
RR
MALE
PURE FOR
RED EYE
COLOUR
FEMALE
PURE FOR
BROWN EYE
COLOUR
rr
R
SPERM
EGG.
r
ZYGOTE
Rr
FIRST HYBRID GENERATION
ALL INDIVIDUALS RED-EYED.

FIGURE 17
Inheritance of Red and Brown Eye Colour in Fruit Fly. The diagram shows the result of crossing between individuals pure for red and brown eye colour. R denotes gene for red eye colour which is dominant; r denotes gene for brown eye colour which is recessive. Red eyes shown as black and brown as shaded. Sperm is shown worm-like with a head and a tail while egg is shown as cylindrical body with projections at top. (From G. Hardin, *Biology—Its Human Implications*. W. H. Freeman & Co., San Francisco, California). [See p. 45].

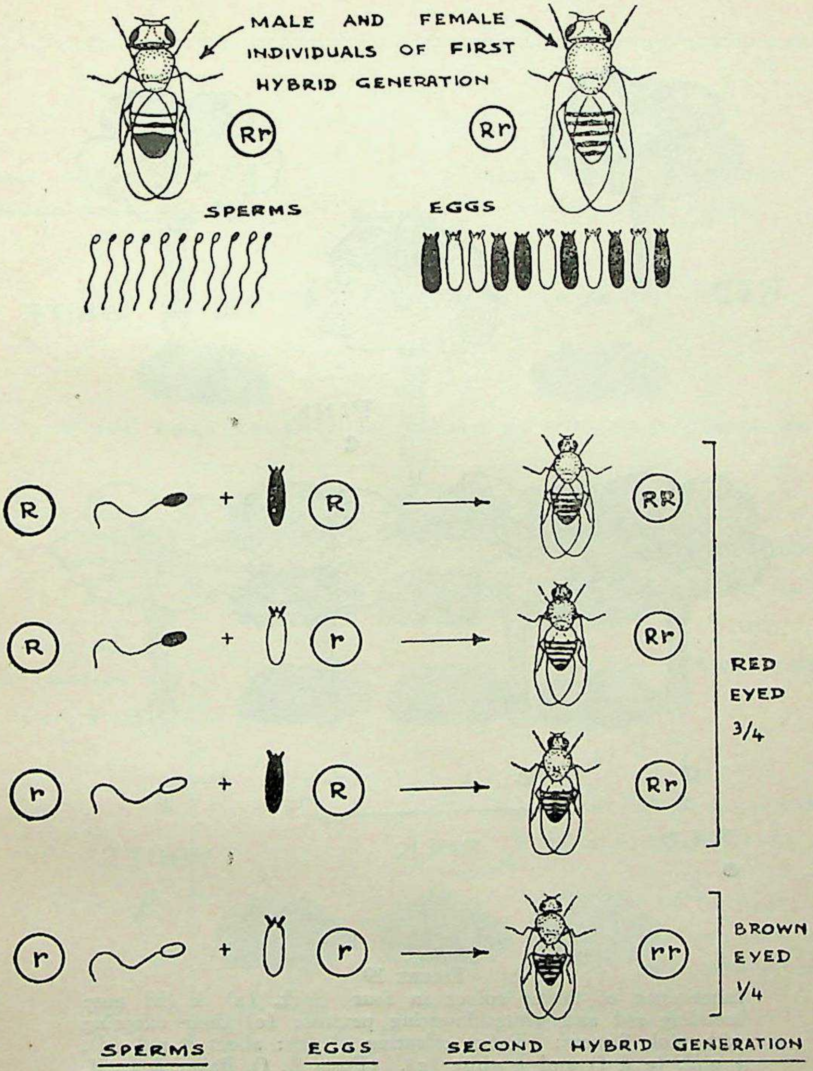

MALE AND FEMALE INDIVIDUALS OF FIRST HYBRID GENERATION
Rr
Rr
SPERMS
EGGS
R
+
R
RR
R
+
r
Rr
r
+
R
Rr
RED EYED 3/4
r
+
r
rr
BROWN EYED 1/4
SPERMS
EGGS
SECOND HYBRID GENERATION

FIGURE 18
Inheritance of Red and Brown Eye Colour in Fruit Fly. The diagram shows the result of mating between two individuals of the first hybrid generation shown in fig. 17. R denotes gene for red eye colour which is dominant; r denotes gene for brown eye colour which is recessive. Red eyes shown as black and brown as shaded. Sperms are shown worm-like with a head and a tail while eggs are shown as cylindrical bodies with projections at the top. Note that the sperms and eggs have been shown as of two kinds only for the sake of clarity and not because they can be distinguished by their appearance. (From G. Hardin, *Biology—Its Human Implications*. W. H. Freeman & Co., San Francisco). [See pp. 45, 47].

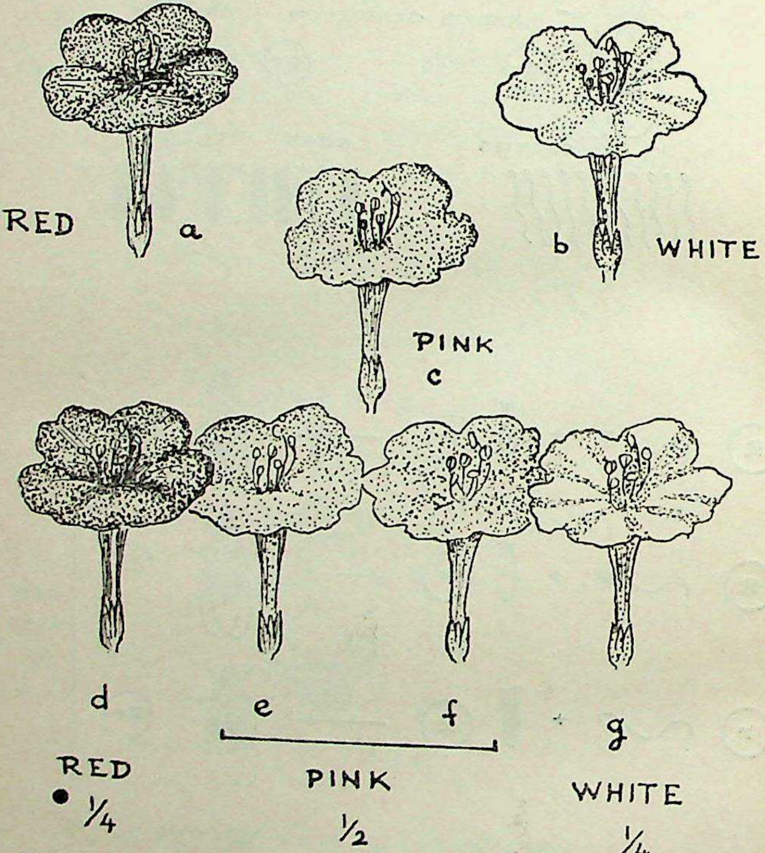

RED
a
b
WHITE
PINK
c
d
e
f
g
RED
1/4
PINK
1/2
WHITE
1/4

FIGURE 19
Inheritance of flower colour in four-o'clock. (a) & (b) pure breeding red and white flowering parents; (c) their offspring with pink flowers; (d)-(g) offspring of (c): about $\frac{1}{4}$ red (d), $\frac{1}{2}$ pink (e & f) and $\frac{1}{4}$ white (g). (From A. O. Baker & L. H. Mills, *Dynamic Biology Today*, Rand McNally & Co., New York). [See p. 48].

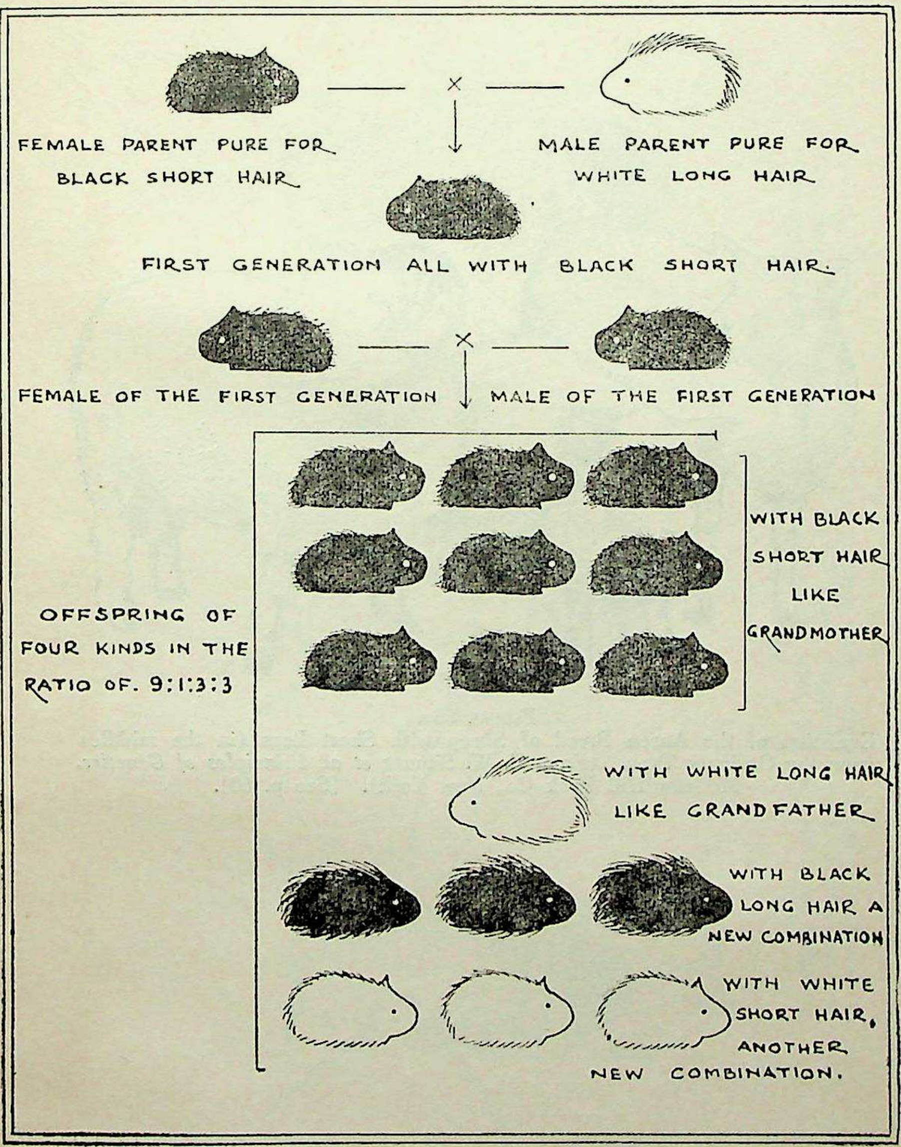

FEMALE PARENT PURE FOR BLACK SHORT HAIR
×
MALE PARENT PURE FOR WHITE LONG HAIR
FIRST GENERATION ALL WITH BLACK SHORT HAIR.
×
FEMALE OF THE FIRST GENERATION
MALE OF THE FIRST GENERATION
OFFSPRING OF FOUR KINDS IN THE RATIO OF. 9:1:3:3
WITH BLACK SHORT HAIR LIKE GRANDMOTHER
WITH WHITE LONG HAIR LIKE GRANDFATHER
WITH BLACK LONG HAIR A NEW COMBINATION
WITH WHITE SHORT HAIR, ANOTHER NEW COMBINATION.

FIGURE 20

Inheritance of Hair Characters (black or white and long or short) in Guinea Pigs. For explanation see text. (From A. O. Baker & L. H. Mills, *Dynamic Biology Today*, Rand McNally & Co., New York). [See p. 48].

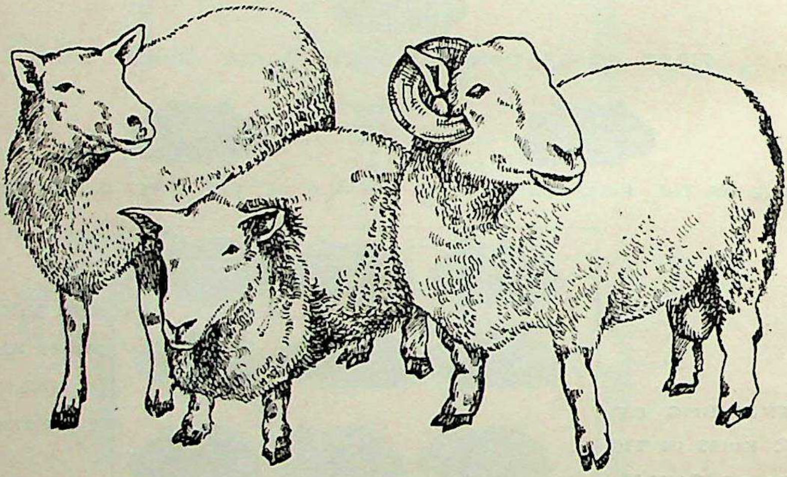


FIGURE 20 a
Evolution of the Ancon Breed of Sheep with Short Legs (in the middle) from the Ordinary Type. (From E. W. Sinnott *et al*, *Principles of Genetics*. McGraw Hill Book Co., New York). [See p. 60].

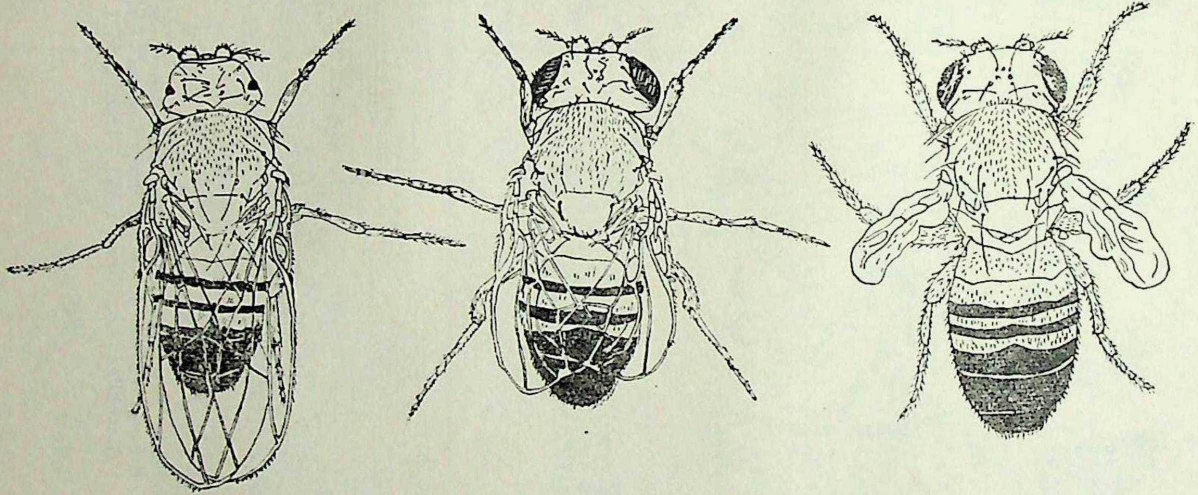


FIGURE 20 b-d
Mutations in Fruit Fly. The figure on the left shows mutation affecting the eyes and the other two show mutation affecting the wings. (From T. Dobzhansky, *Evolution, Genetics and Man*, John Wiley & Sons, New York). [See p. 60],

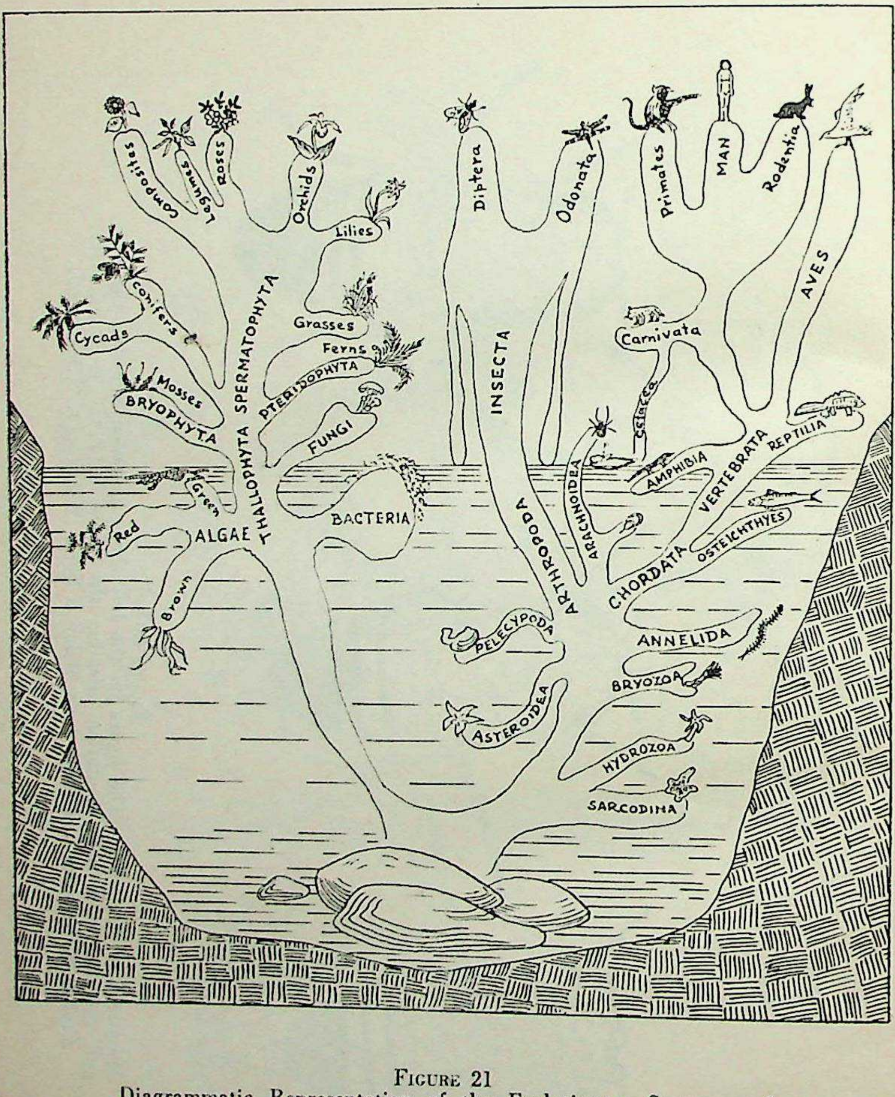

Composites
Legumes
Roses
Orchids
Lilies
Conifers
Cycads
Grasses
Ferns
PTERIDOPHYTA
Mosses
BRYOPHYTA
SPERMATOPHYTA
THALLOPHYTA
FUNGI
Green
Red
ALGAE
Brown
BACTERIA
Diptera
Odonata
INSECTA
ARTHROPODA
ARACHNOIDEA
PELECYPODA
ASTEROIDEA
Primates
MAN
Rodentia
AVES
Carnivata
Cetacea
REPTILIA
AMPHIBIA
VERTEBRATA
OSTEICHTHYES
CHORDATA
ANNELIDA
BRYOZOA
HYDROZOA
SARCODINA

FIGURE 21
Diagrammatic Representation of the Evolutionary Sequence of Living Beings. (After J. W. Mavor, *General Biology*. The Macmillan Co., New York). [See p. 57].

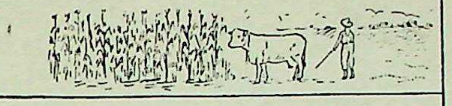
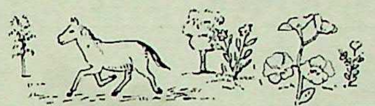
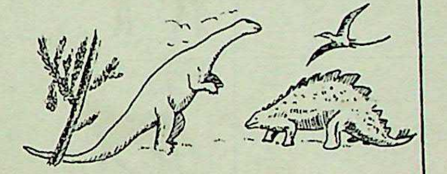
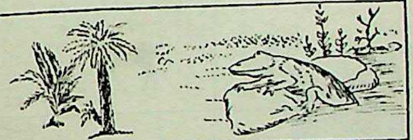
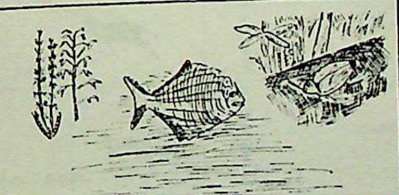
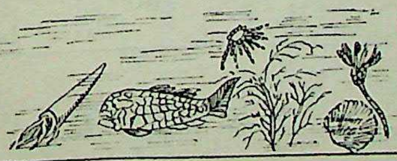
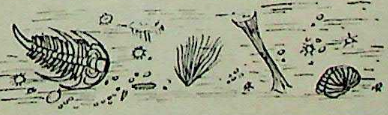
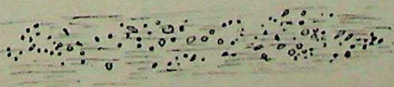
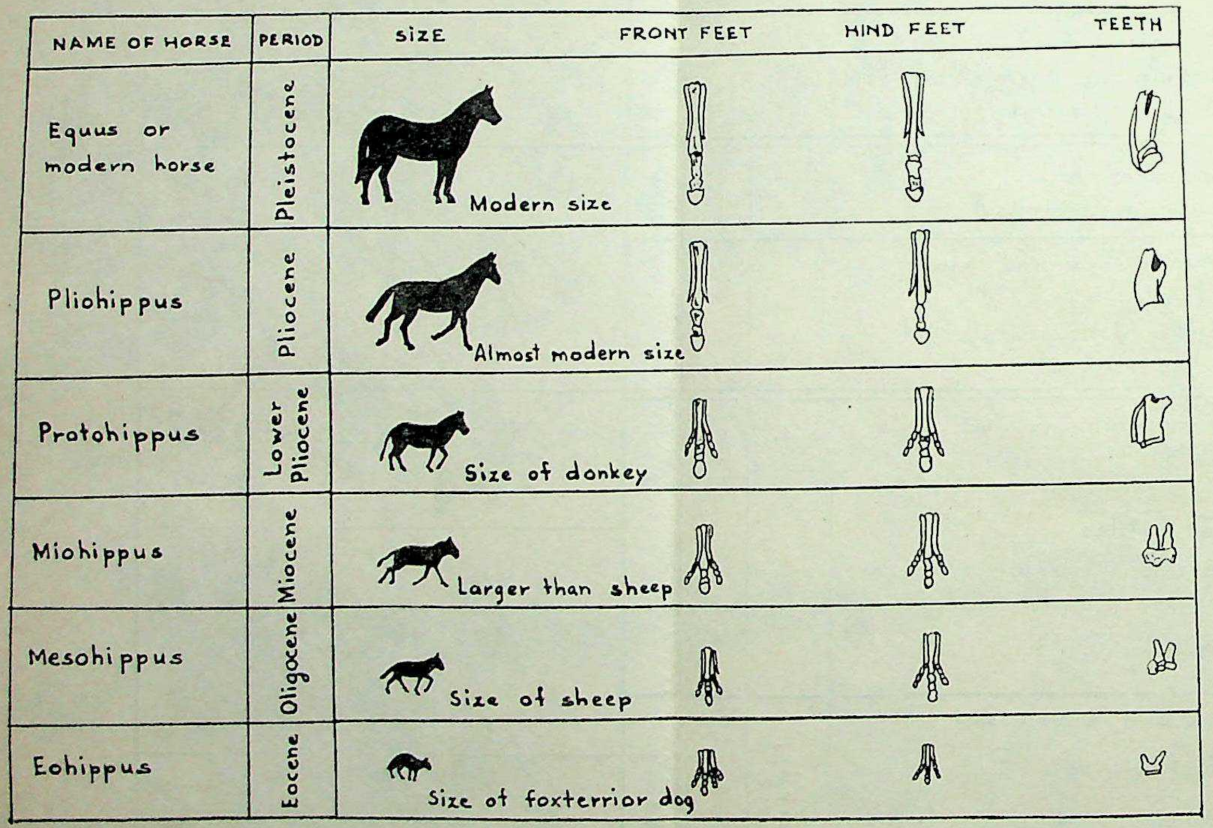
ERAS	SUBDIVISIONS OF ERAS		Age of the rocks	Plant Fossils				Animal Fossils							
CENOZOIC 3%	QUATERNARY			Dominance of flowering plants				Dominance of man							
	TERTIARY		60 millions years	Culmination of land flora.				First men culmination of mammals Rise of an thropoids.							
MESOZOIC 7%	Late mesozoic	Cretaceous	200 million years	Flowering Plants				Rise of archaic mammals and birds							
	Early mesozoic	Jurassic		Spread of cycads and conifers.				Primitive mammals and birds							
		Triassic						Giant reptiles (dinosaurs) and primitive mammals.							
PALEOZOIC 17%	Late paleozoic	Permian	540 million years	Gymnosperms Extensive forests of gigantic ferns, horsetails & clubmasses				Spread of amiphibians and primitive insects							
		Pennsylvanian						Spread of reptiles							
		Mississippian						Ancient sharks							
	Middle paleozoic	Devonian		First spread of farests				Rise of fishes and amphibians							
		silurian		Firs and plants				Primitive fishes Sea scorpions							
	Early paleozoic	Ordovician						First primitive vertebrates							
		Cambrian			ferns, horsetails etc.	seed bearing plants	flowering plants	Dominance of trilobites Invertebrates	fishes	amphibians	reptiles	mammals & birds	anthropoids	human beings	
PROTEROZOIC AND				Algae	No	No	No	Protozoa sponges	No	No	No	No	No	No	
ARCHEOZOIC 73%			2000 millions years	Evidence of the existence of life but no recognizable fossils											

FIGURE 21a. Evolutionary Sequence of Living Organisms as Revealed by Fossils (From J. W. Mavor, *General Biology*. The Macmillan Co., New York and A. O. Baker and L. H. Mills, *Dynamic Biology Today*, Rand McNally & Co., New York). [See p. 67].



NAME OF HORSE	PERIOD	SIZE	FRONT FEET	HIND FEET	TEETH
Equus or modern horse	Pleistocene	Modern size			
Pliohippus	Pliocene	Almost modern size			
Protohippus	Lower Pliocene	Size of donkey			
Miohippus	Miocene	Larger than sheep			
Mesohippus	Oligocene	Size of sheep			
Eohippus	Eocene	Size of foxterrior dog			

Figure 22

Evolution of the horse as suggested by fossils—an oversimplified representation. (From A. O. Baker and L. H. Mills, *Dynamic Biology Today*, Rand McNally & Co., New York). [See p. 71].

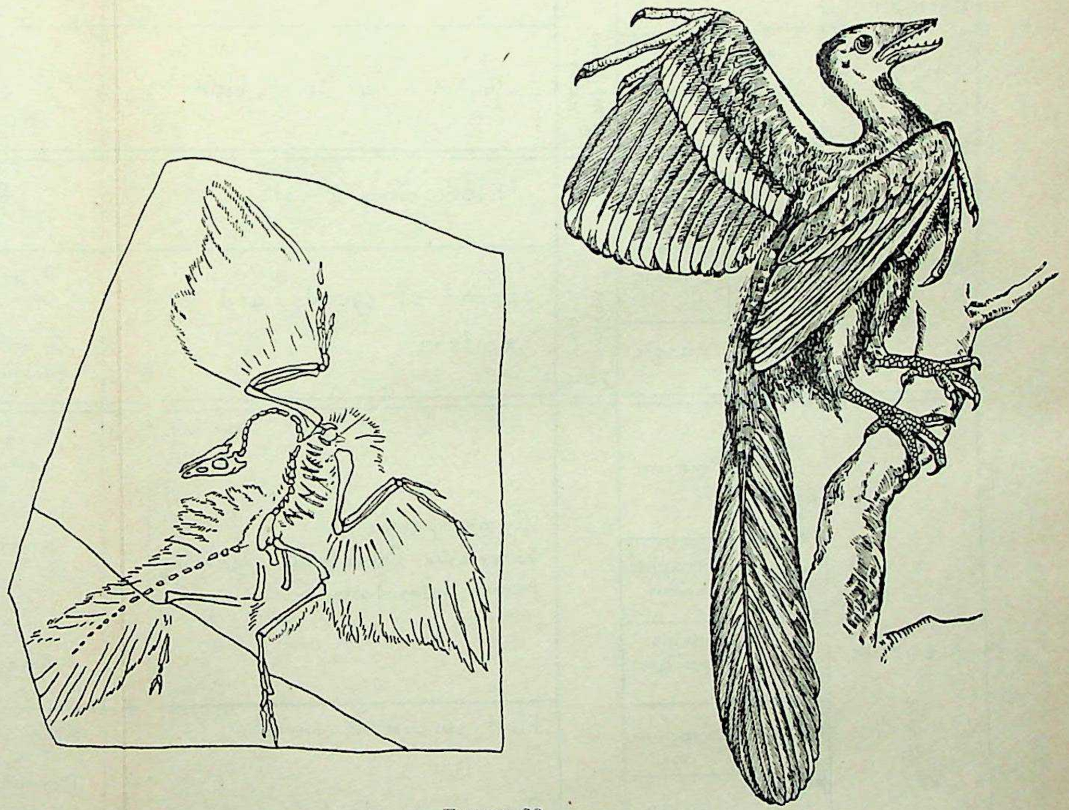


Figure 23

The left-hand sketch shows the fossils of the reptile-bird, *Archaeoptery* and the right-hand shows the reptile-bird as it probably appeared in life. (Left-hand sketch from R. A. Stirton, *Time, Life and Man—The Fossil Record*, John Wiley & Sons, New York. Right-hand sketch from C. M. Beadnell, *A Picture Book of Evolution*, Watts & Co. London). [See p. 73].

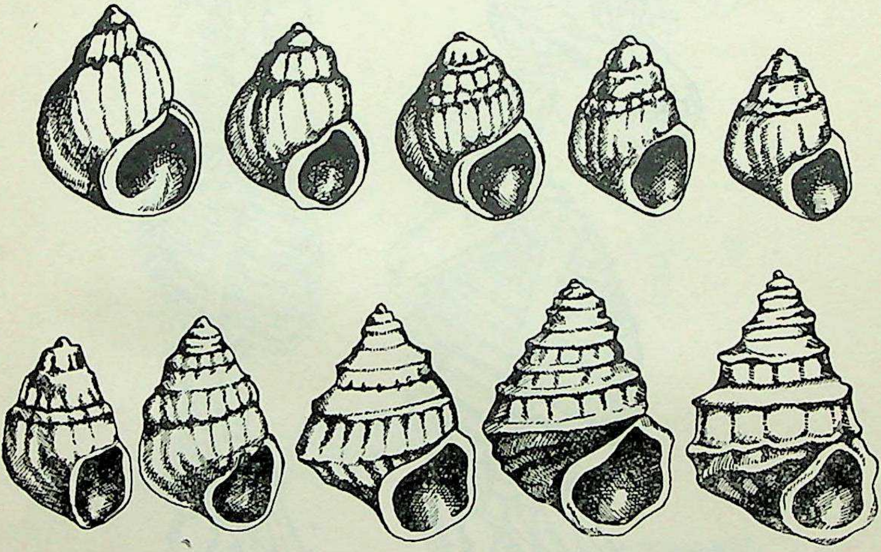


FIGURE 24
Paludina, showing transition from one form to another. (From T. Dobzhansky, *Evolution, Genetics and Man*, John Wiley & Sons, New York). [See p. 74].

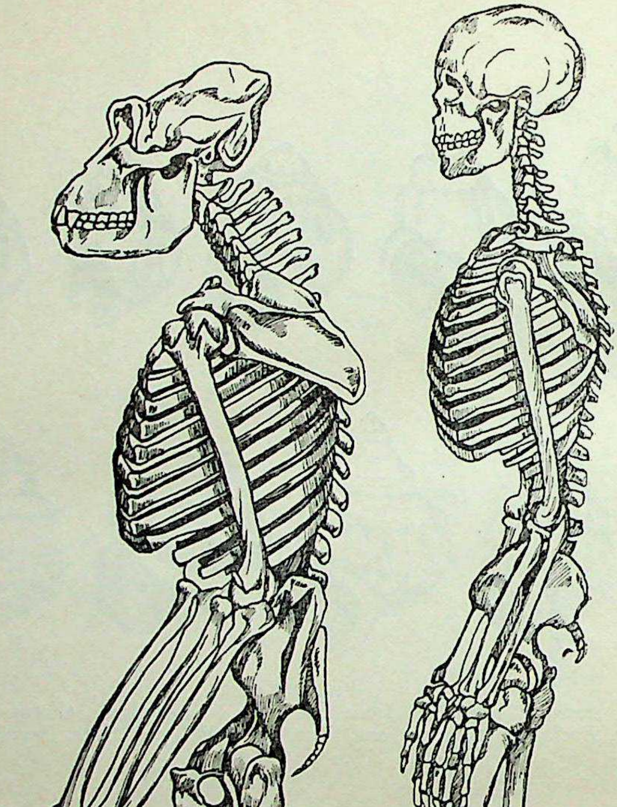


FIGURE 25
Skeletons of Gorilla and Man (From H. Wheeler, *The Miracle of Life*, The Home Library Club). [See p. 75].

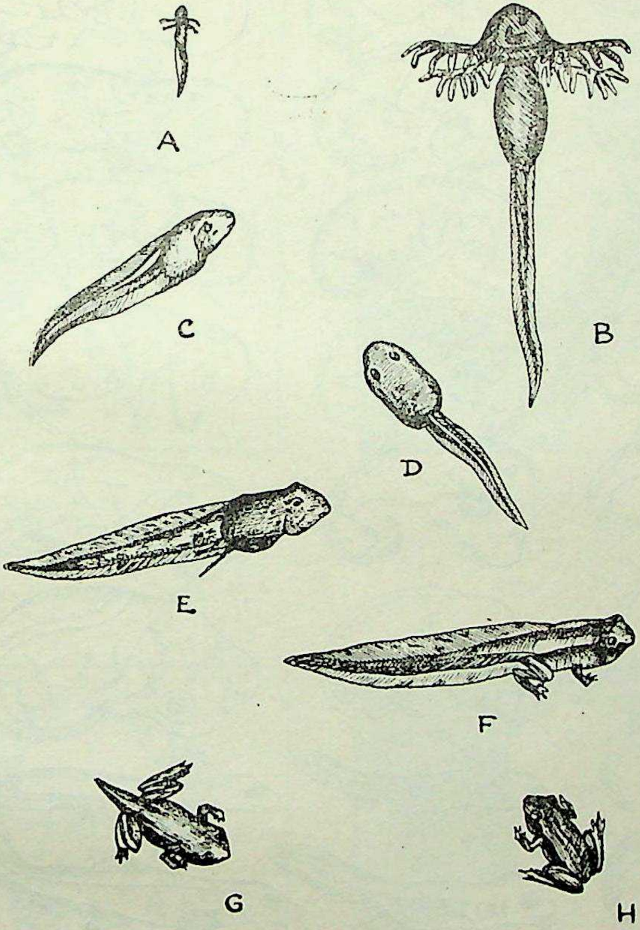


FIGURE 26
Development of the Frog. Note the fish-like stages of the embryo in (a) to (e). In (f) the hands and legs are clearly seen, (g) shows a young frog with a tail and in (h), the tail has completely disappeared. (From C. M. Beadnell, *A Picture Book of Evolution*, Watts & Co., London). [See p. 76].

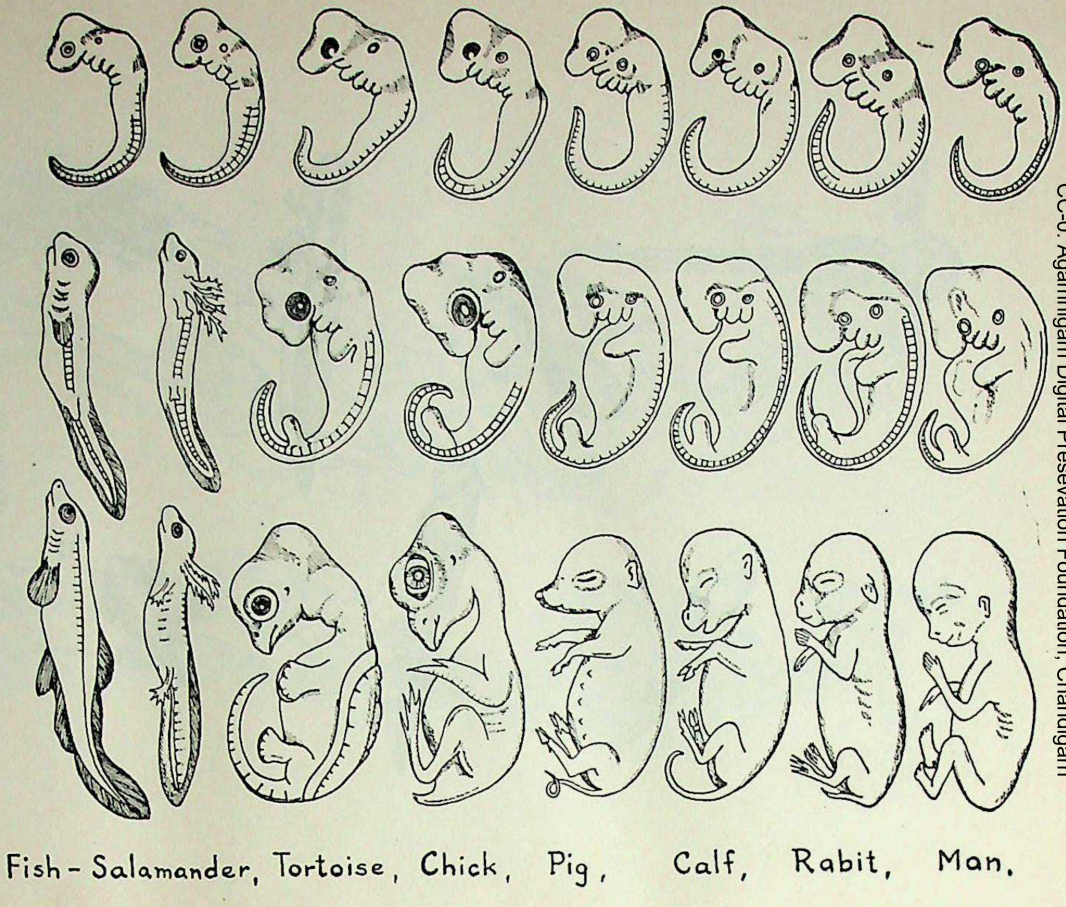

Fish - Salamander, Tortoise, Chick, Pig, Calf, Rabit, Man.

FIGURE 27

Comparison of embryos of Different Animals at Three Stages of Development. The top row shows the youngest stage, the middle row an intermediate stage and the bottom row the oldest stage. (From J. W. Mavor, *General Biology*. The Macmillan Co., New York). [See p. 76].

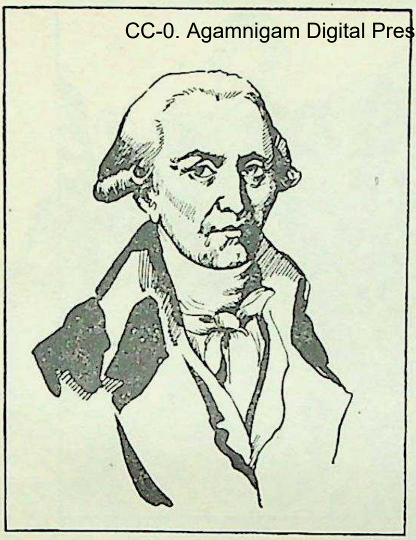


Figure 28
JEAN BAPTISTE LAMARCK
(From E. W. Sinnott *et al*, *Principles of Genetics*, McGraw Hill Book Co., New York). [See p. 80].

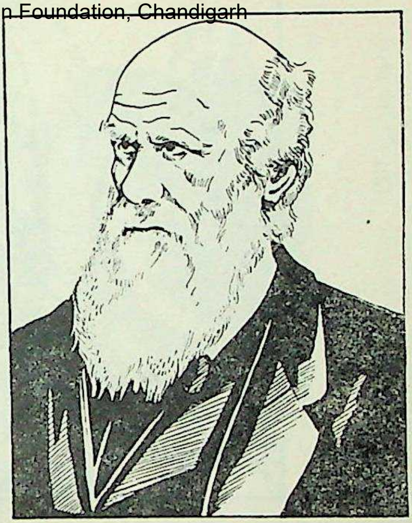


Figure 28a
CHARLES DARWIN
(From H. Wheeler, *The Miracle of Life*, The Home Library Club). [See p. 81].

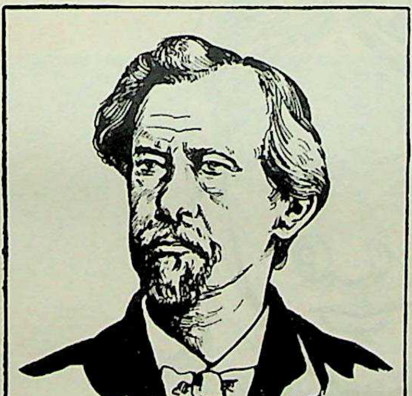


Figure 28b
HUGO DE VRIES
(From R. H. Lock, *Variations, Heredity and Evolution*, John Murray, London). [See p. 84].

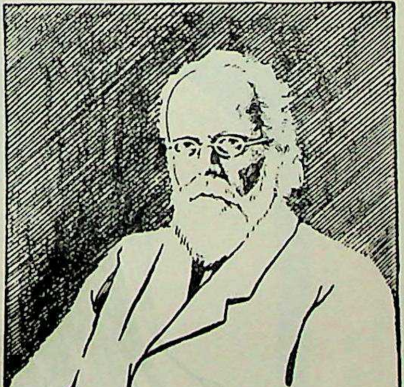


Figure 29
AUGUST WEISMANN
(From E. W. Sinnott *et al*, *Principles of Genetics*, McGraw Hill Book Company, New York). [See p. 83].

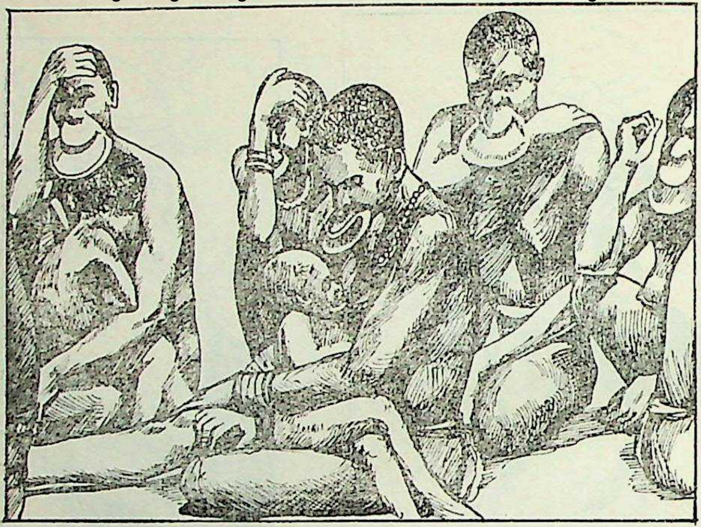


FIGURE 30
A Group of People from the Lake Chad Region of French Equatorial Africa. Note the lips. (From C. M. Beadnell, *A Picture Book of Evolution*, Watts & Co., London). [See p. 85].

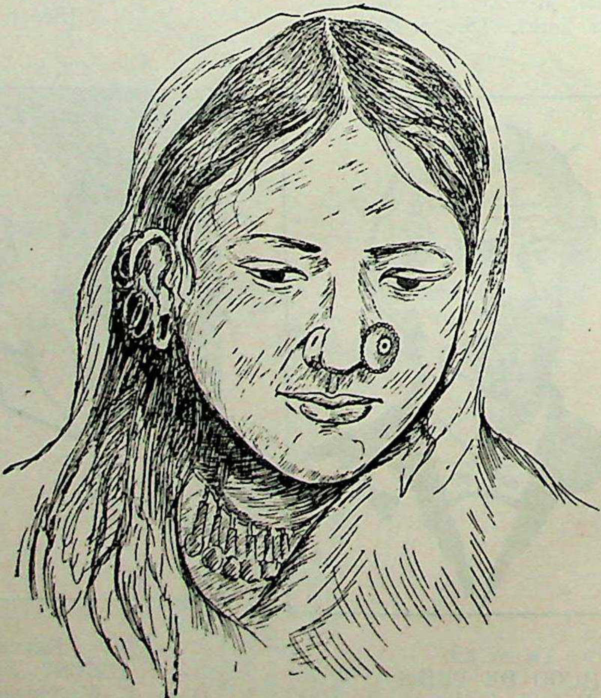


FIGURE 31
Sketch of an Indian Village Lady. Note the nose and ear pierced for wearing ornaments. [See p. 85].

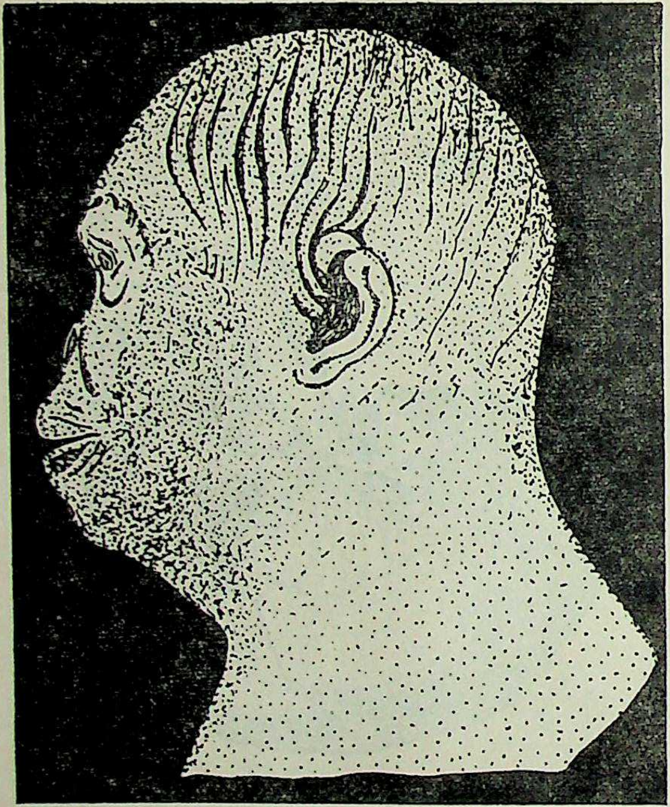


FIGURE 32
Prof. Dar's reconstruction of the head and neck of Australopithecus (half natural size)
(From *New Discoveries Relating to the Antiquity of Man*, by Keith, Sir, Arthur—Published by Williams & Norgate, London—1931). [See p. 123].

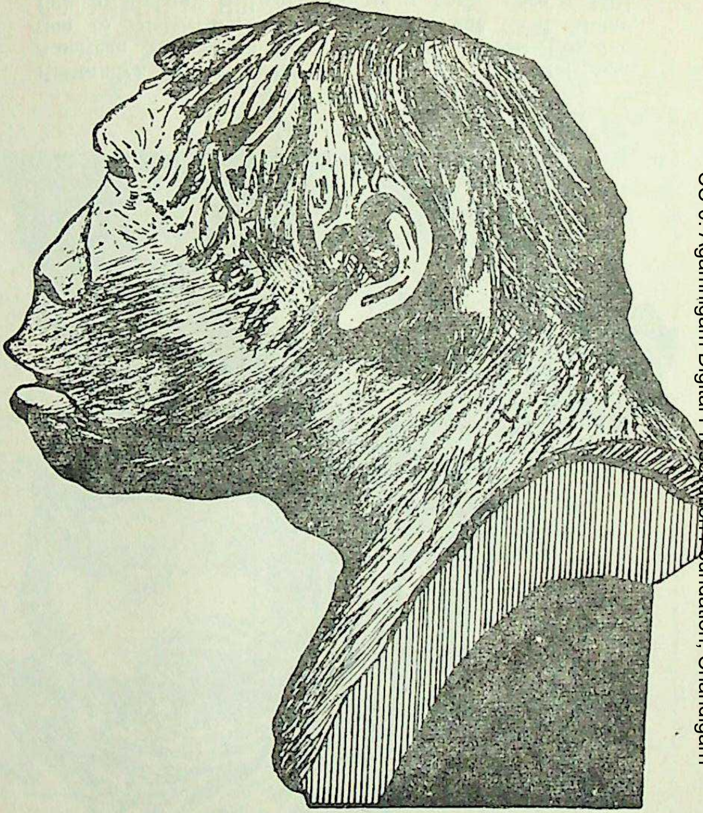


FIGURE 33
Restoration of the Java apeman (Pithecanthropus). (J. H. McGregor, American Museum of Natural History, From Introduction to *Historical Geology*, by Raymond Cecil Moore. Published by McGraw Hill Book Company, New York). [See p. 125].

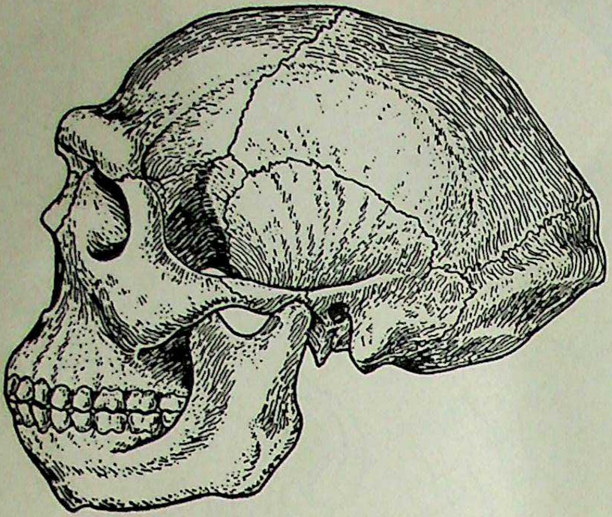


Figure 34

Reconstruction of female Sinanthropus skull (after Montague, following Weidenreich). There is a surprisingly heavy supraorbital torus for a female, the forehead is retreating, the arch of the skull vault is low, prognathism is pronounced and there is no forward projection of the chin. (From Human Evolution—*Reading in Physical Anthropology*; ed. by Noel Korn and Harry Reece Smith, Valley Junior College, Van Nuys, California. Published by Henry Holt and Co. Inc. New York. [See p. 127].

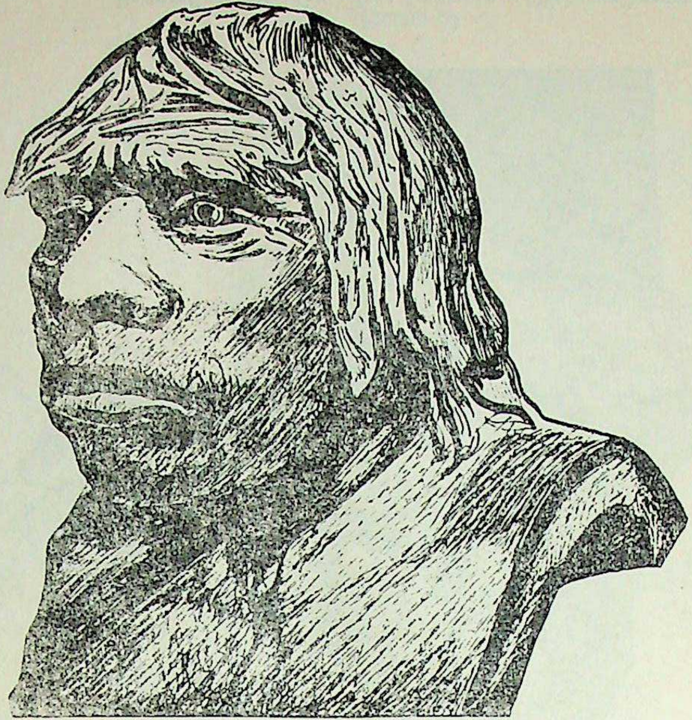


Figure 35

Restoration of Neanderthal man. (J. H. McGregor, American Museum of Natural History) From: Introduction to *Historical Geology*, by Raymond Cecil Moore. Pub. by McGraw Hill Book Co., New York. [See p. 130].

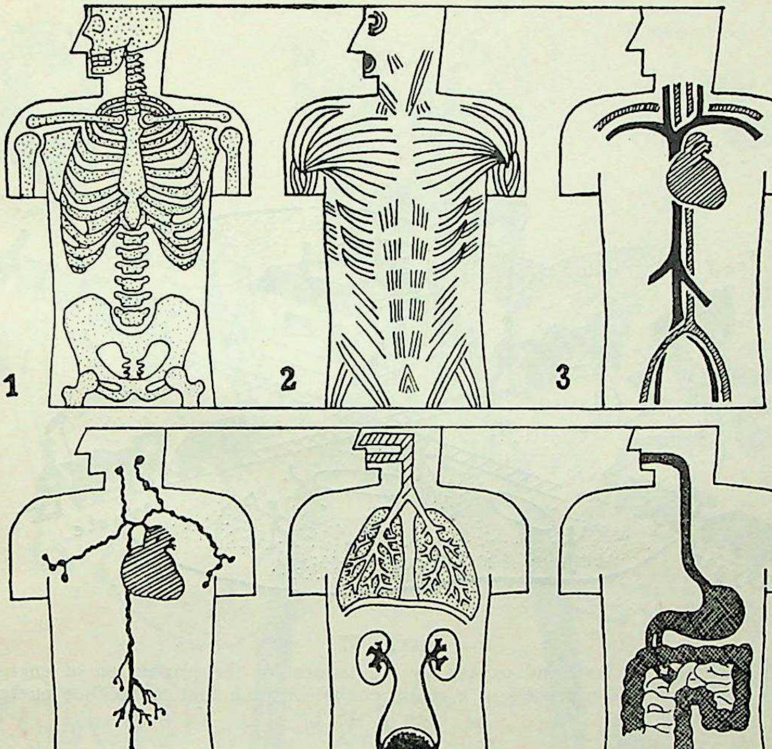


FIGURE 36
The systems of the body. 1. Skeletal; 2. Muscular; 3. Circulatory; 4. Lymphatic; 5. Respiratory and Urinary; 6. Digestive; 7. Ductless glands; 8. Nervous; and 9. Special senses and autonomic nervous system. [See p. 145].

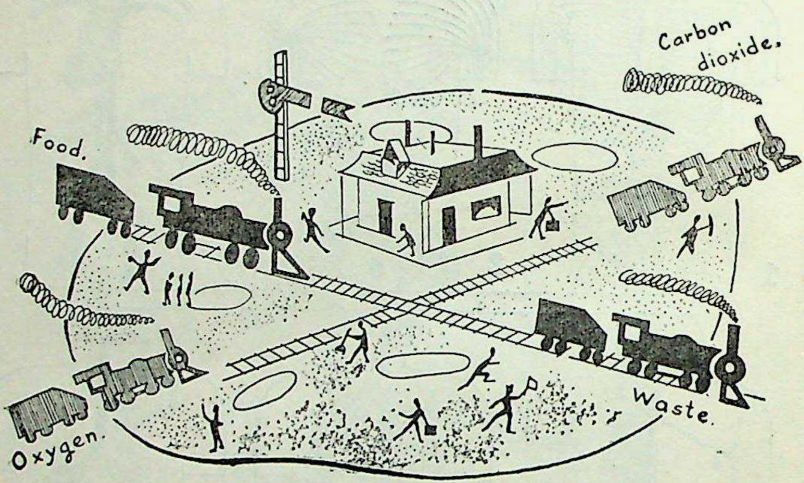

Carbon dioxide.
Food.
Oxygen.
Waste.

FIGURE 37
Assimilation of food and oxygen by the tissues for the production of energy. is analogous to the process of a steam engine burning fuel to produce energy. [See p. 151].

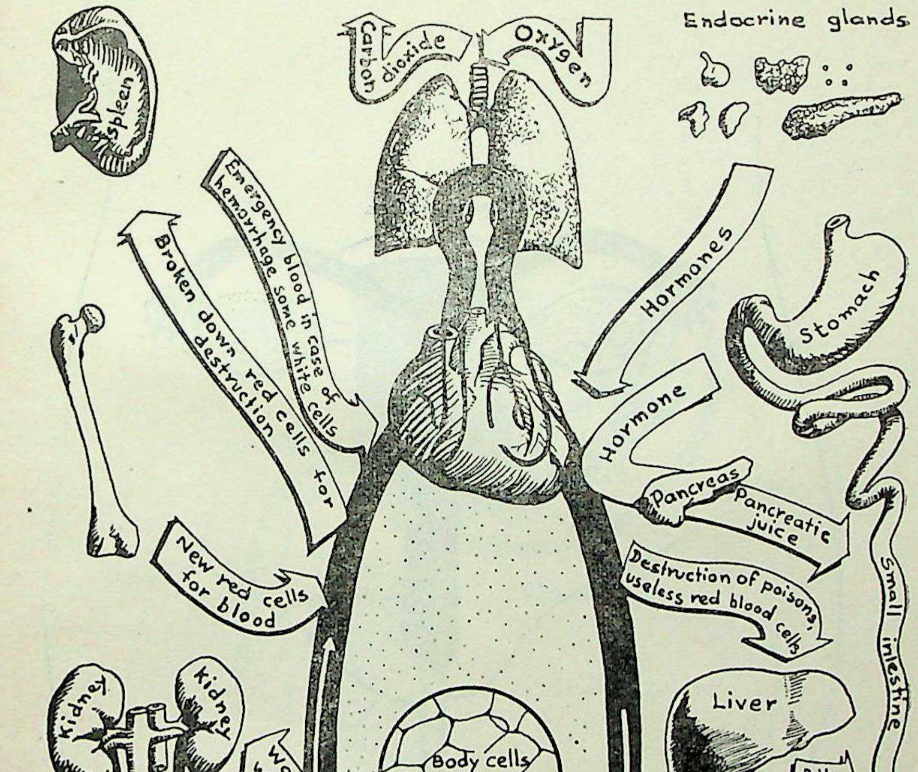

Spleen
Carbon dioxide
Oxygen
Endocrine glands
Emergency blood in case of hemorrhage some white cells
Broken down red cells for destruction
Hormones
Stomach
Hormone
Pancreas
Pancreatic juice
New red cells for blood
Destruction of poisons, useless red blood cells
Small intestine
Kidney
Kidney
Water wastes
Liver
Bile
Body cells
Digested food
Water salt wastes
Large intestine
Sweat gland
Bladder
Elimination of liquid wastes
Elimination of undigested food.

FIGURE 38
Transport of oxygen and fuel, removal of waste products—blood circulation. [See p. 154].

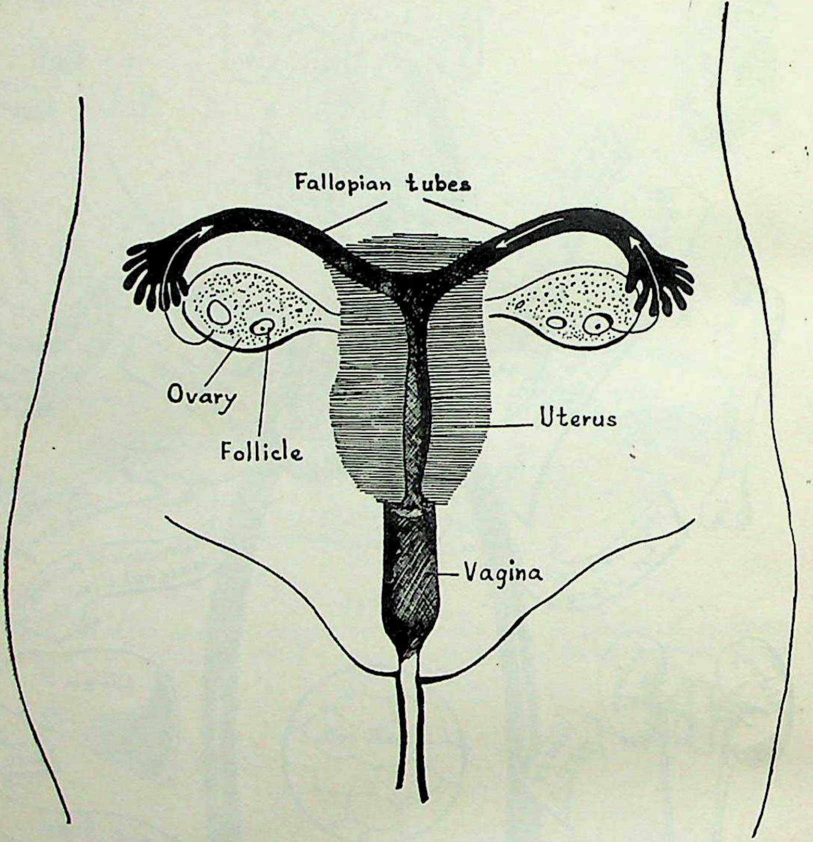

Fallopian tubes
Ovary
Follicle
Uterus
Vagina

FIGURE 39
Female Reproductory Organs. [See p. 160].

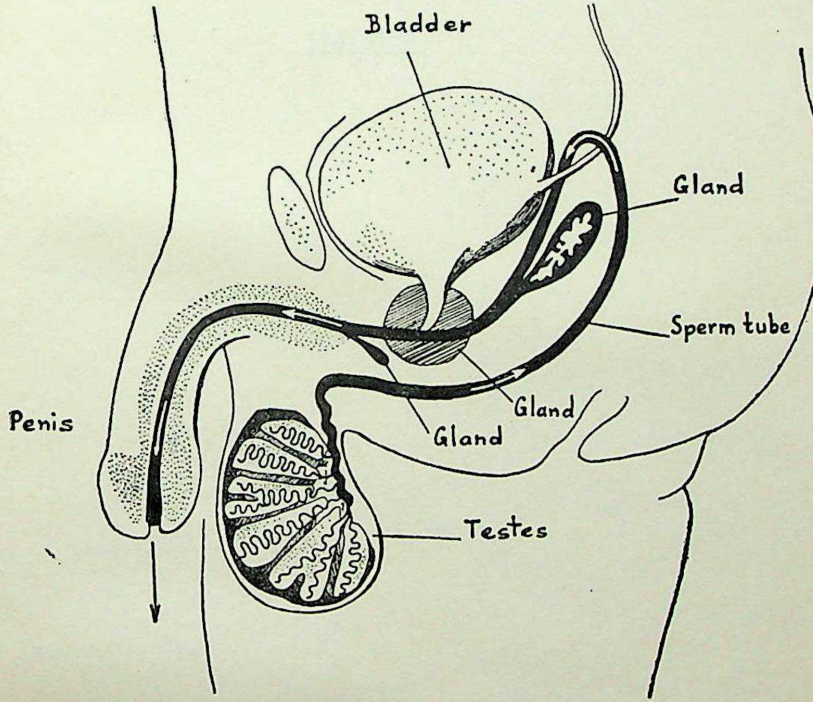

Bladder
Gland
Sperm tube
Penis
Gland
Gland
Testes

FIGURE 40
Male Reproductory Organs. [See p. 160].

INDEX

Index

Acid, amino, 147, 151, 155; fatty, 147, 152; oleic, 147; stearic, 147
Adrenal glands, 22
Aesthetic, 116
Agassiz, 110
Age, 3, 67, 96, 111; dark, 138; ice, 109, 110, 111, 112, 120, 121; of amphibians, 69; of Cycads, 69; of mummies, 134; of reptiles, 69; Pleistocene, 112; stone, 134
Albertus Magnus, 139
Alga, 12, 26, 27, 57, 68
Amino acid, 147, 151, 155
Amoeba, 13, 27, 28, 29, 36
Amphibians, age of, 69
Anatomical, characteristic, 113
Anatomy, 124, 134, 135, 139, 141, 142, 143; of the Neanderthal man, 131
Ancestry of man, 103
Ancon, 60, 77
Anderson, 127
Angiosperms, 13
Animal, Kingdom, 13, 16, 133; thinking, 160
Anthropoids, 13, 69, 107, 108, 112, 115, 117, 118, 119, 120, 121, 122, 124, 125, 129; anthropoid stage, 123
Antibody, 166, 167
Ape, 4, 14, 16, 57, 59, 61, 75, 93, 112, 127, 128, 130, 131
Aqueous, 66
Arab renaissance, 140
Archaeopteryx, 69, 72, 73
Archaeozoic, 67, 68, 104
Aristotle, 79, 136
Arteries, 21, 154, 168
Articulation, 117
Ascaris, 36, 42
Assimilation, 151
Australo, 124
Australopithecus, 121, 123, 124, 128
Averroes, 141
Avicenna, 141

Bacteria, 12
Beriberi, 5
Bible, 79
Bile, 137
Biological inheritance, 41
Biologists, 11, 13, 14
Biology, 3, 5, 13, 41, 78, 79
Black, Prof., 127
Blood, cell, 18; circulation, 154
Body of Neanderthal man, 131
Breathing system, 19, 20
Broom, Dr., 121
Brunckner, 110
Buffon, 79
Burrows, 68

Calcareous shells, 13
Canis familiaris, 15
Capillary, 154; lymph, 151, 152
Carbohydrates, 20, 30, 31, 146, 147, 150, 152, 153, 156
Carboniferous period, 69
Carnivora, 107
Carpels, 35
Cataclysms, 106
Cell, 18, 21, 23, 24, 26, 27, 28, 29, 30, 31, 32, 33, 34, 36, 37, 38, 39, 42, 46, 83, 86, 89, 147, 154, 155, 157, 158, 160; division, 36; protoplasmic, 89; structure, 28
Cenozoic, 68, 69, 104, 109; era, 69, 70, 71, 104, 105, 106, 107, 108
Cerebrum, 160
Chao Kao Tain, 127
Chick Hillock, 126
Chi Ko San, 127
Chimpanzee, 108, 122, 128
Chlamydomonas, 29
Chlorophyll, 12, 24, 27, 32
Chloroplast, 29
Choler, 136
Chordata, 133
Chromosome, 36, 37, 38, 39, 41, 42, 43, 44, 47, 49, 81, 85, 86, 89; mechanism, 97; structure of, 86

INDEX

Circulation, blood, 154
Circulatory system, 19, 21, 23, 26
Colchicine, 42
Common salt, 155
Contours, 122
Copernicus, 143
Cosmic evolution, 97
Cow-tree, 4, 7
Cranial Capacity, 122, 128
Cranium, 125, 131
Cro-Magnon, 132
Cycads, 12; age of, 69
Cytoplasm, 28, 29, 37, 42
Cytolymph, 29

Dark ages, 138, 140
Darwin, 79, 81, 82, 86, 87, 98, 130; theory, 81, 83, 87; theory of evolution, 93
Darwinism, 83
De Vries, Hugo, 59, 79, 84, 87
Defence system of the human body, 165
Die Eiszeit, 110
Digestion, 151
Digestive, 19, 20; juices, 20; system, 21
Dinosaur, 69, 126
Disease, due to hormonal unbalance, 163; due to foreign bodies, 164; due to malnutrition, 163; ridden, 168
Drosophila melanogaster, 60
Drunten, 110
Dryopithecus, 108
Dubois, 124, 125
Ductless glands, 156
Duodenum, 151

Einstein, 98
Elements, 6
Embryo, 35, 51, 76, 77, 140
Embryology, 76
Empedocles, 136
Endocrine, glands, 21, 156; system, 19, 21
Energy, 6, 8, 146, 147; release of, 152
Enzymes, 30, 31, 150, 151, 152, 155
Eocene, 71, 106; epoch, 106
Eohippus, 71
Epilepsy, 135
Epoch, 67, 108
Equus, 71
Era, 68, 81, 104; Cenozoic, 69, 70, 71, 104, 105, 106, 107, 108; mammalian, 105; Mesozoic, 105, 126; Palaeozoic, 68, 105; Psychozoic, 70
Erodes, 65
Eucalyptus, 6
Euglena, 27, 29
Evidence of evolution, 74
Evolution, 53, 70, 72, 77, 79, 87, 94, 95, 96, 98, 99, 121, 127, 128, 129, 130, 132; evidence of, 74; mechanism of, 79, 80, 84, 85; mental, 131; of life, 103; of man; 101; principle of, 78; story of, 4; theory of, 73, 80, 81
Excretion, 156
Excretory system, 19

Fats, 20, 21, 30, 31, 90, 146, 147, 148, 150, 152, 153
Fatty acids, 147, 152
Female gamets, 34, 35, 38
Ferns, 24, 68
Fern-like, 69
Fertilization, 34, 35
Ficus bengalensis, 15
Ficus carica, 15
Ficus glomerata, 15
Ficus religiosa, 15
Flints, 69
Foreign bodies, disease due to, 164
Fossil, 64, 65, 66, 67, 68, 69, 70, 72, 74, 107, 110; evidence, 64, 67, 70, 72; snails, 74; study of, 64
Four Humours, theory of, 136
Fruit fly, 36, 37, 42, 43, 45, 48, 50, 60, 61
Fungi, 12

Galen, 137, 138, 141, 142, 143
Galileo, 110, 143
Gametes, 46, 47, 83; female, 34, 35, 38; male, 34, 35
Gastric juices, 151
Gene, 44, 46, 47, 49, 81, 85, 86; mutation, 86

Genealogy, 103, 104, 128
Genera, 16, 74
Genetic, 41, 42, 45, 47, 50, 51, 85, 87; constitution, 48; importance of, 49; study of, 49
Genus, 16, 123, 127, 128, 129, 130
Germ, 5, 155, 166, 167; cell, 81, 86
Germplasm, 84
Gills, 76, 77
Glands, ductless, 156; endocrine, 156
Glucose, 146, 150, 151, 152, 155
Glycerine, 147, 151, 152
Glycogen, 147, 152
Gobi desert, 126
Gorilla, 75, 122, 123
Grimaldi, 132
Gymnosperms, 13, 69

Haeckel, 124, 125
Haemoglobin, 154
Haemorrhage, 149
Harvey, 141, 143
Heidelberg, 124
Hepatic portal vein, 151
Heredity, 40, 41, 42, 85; meaning of, 40; mechanism of, 45
Hippocrates, 135, 136, 137, 141, 143
Holocene, 111
Hominidae, 133
Homo heidelbergesis, 124
Homo neanderthalensis, 70, 130
Homo sapiens, 15, 22, 70, 105, 132, 133, 144
Hormonal unbalance, disease due to, 163
Hormones, 5, 22, 23, 157
Horsetails, 12
Human body, 3; defence system of, 165
Human evolution, 97
Human mind, 118
Hybridization, 61, 77, 87
Hydra, 25, 26, 36
Hydrophobia, 89
Hypnotism, 99

Ibn-Haytham, 141
Ice age, 109, 110, 111, 112, 120, 121
Incantations, 139
Insulin, 157, 163
Invertebrate, 68

Java ape-man, 70, 73, 126

Karyolymph, 29

Lamarck, 79, 80, 81, 83, 86; theory of, 81; theory of evolution, 79
Language, of gestures, 116, 117, 119; of sound, 117, 119
Larynx, 117
Late Paleozoic, 69
Lead salts, 164
Life, a riddle, 6; origin of, 89
Linnaeus, Karl, 132
Liverworts, 12
Living beings, 3, 5, 8, 11, 53, 58, 63, 67, 103
Living organism, 6, 8, 94, 105
Lohan, Dr., 127
Lycopods, 12
Lymph, 166; capillaries, 151, 152; vessels, 165

Macrocosm, 139
Maggots, 90
Male gametes, 34, 35
Malnutrition, 164; disease due to, 163
Mammalia, 133
Mammalian era, 105
Mammals, 4, 14, 16, 19, 51, 57, 59, 68, 69, 70, 72, 76, 77, 92, 104, 105, 106, 107, 108
Mammary glands, 105
Mammoth, 64
Mangifera indica, 15
Marlot, 110
Masticate, 115
Meaning of heredity, 40
Mechanism, of evolution, 79, 80. 85, 87; of heredity, 45
Melancholic phlegmatic, 137
Melancholy, 136
Mellifluence, 117
Mendel, 45, 47, 48, 85; principle, 46, 86
Mendelism, 45
Mental evolution, 131
Mesoglea, 26

Mesozoic, 68, 69, 104; era, 105, 108, 126; period, 72
Metabolism, 8, 9, 155, 157, 163
Metabolic waste, 156
Mimosa, 8
Mineral salts, 146
Miocene, 107, 108
Missing Links, 120
Molecule, 147
Mosses, 12
Multifarious plants, 104
Mummies, age of, 134
Muscular system, 19
Mutation, 59, 60, 85, 86; genes, 86; theory, 84

Neandertal, 129
Neanderthalensis, 129
Neanderthal man, 70, 73, 129, 130, 131, 132; anatomy of, 131; body of, 131
Nectar, 14
Nerve cell, 18
Nervous system, 19, 21, 22, 33, 156, 157
Neuron, 21
Nodule, 67
Numbers, theory of, 136
Nutritive system, 19, 20

Oleic acid, 147
Oligocene, 106, 107; epoch, 107
Organ, 7, 23, 24, 31, 32, 33, 34, 42
Organic evolution, 58, 59, 63, 64, 67, 72, 78, 79, 96, 103; disease, 168; evidence of, 65; meaning of, 55; the theory of, 57, 74, 76
Organism, 17
Origin of life, 89
Ovary, 34
Ovules, 35
Ovum, 34, 35, 37, 44, 47

Palaeontologists, 67
Palaeontology, 64
Paleocene, 105
Paleopithecus, 108
Paleozoic, 68, 69, 104; era, 68, 105
Palisade tissue, 32
Pancreas, 151, 156, 157
Pancreatic juice, 151
Paramoecium, 29
Parapithecus, 107
Parasites, 168
Pasteur, 167
Pei, Dr., 127
Peking man, 70, 73, 127
Pelvis, 114, 121
Penck, 110
Peptones, 151
Pericasp, 148
Periconodon, 106
Pernicious anaemia, 148
Petrifaction, 64
Phagocytes, 165
Philolaus, 136
Phlegm, 136, 137
Phloem, 24
Photosynthesis, 24, 32
Phyla, 133
Phylum chordata, 133
Physiology, 136, 139, 141, 142, 143
Pithecanthropus, 126, 128, 129; *erectus*, 70, 125
Pithecus, 123, 124
Plaeocene, 111
Plant Kingdom, 12, 13
Plasma, 154, 155, 165
Plato, 136, 138
Pleistocene, 108, 109, 110, 111, 113, 119, 124, 125, 129, 130; age, 112; epoch, 110; era, 129
Plesiadapis, 106
Pliocene, 108; epoch, 106, 108; era, 106
Pollen, 14; grains, 35
Power of reproduction, 18
Preconsul Africanus, 108
Primates, 106, 133; family of, 106
Prodigality, 82
Propleopithicus, 107
Proteins, 20, 30, 31, 90, 146, 147, 150, 151, 152, 153, 155, 164, 166
Proteoses, 151
Proterozoic, 67, 68
Protococcus, 27
Protoplasm, 6, 7, 9, 24, 28, 30, 31, 57, 91; movement of, 7
Protoplasmic body, 28; cells, 9, 18, 89
Protoplast, 28

CC-0. Agamnigam Digital Preservation Foundation, Chandigarh

Protozoa, 164
Psychiatry, 99
Psychozoic era, 70
Ptylin, 151
Putrefaction, 64
Pythagoras, 136

Quinine, 167

Redwood tree, 6
Release of energy, 152
Removal of waste products, 154
Renaissance, Arab, 140
Reproduction, 32, 34, 36, 160; methods of, 35; power of, 18; sexual, 9, 34
Reproductive, organs, 23; system, 19
Reptiles, 4, 14, 59, 61, 69, 72, 75, 92, 105, 108, 126; age of, 69; reptile-bird, 72, 74
Respiration, 24, 153
Rhazes, 141
Rickets, 5
Rodenta, 107

Salamander, 76, 77
Salts, 148, 158; common, 155; lead, 164; mineral, 146
Schimper, 110
Science of life, 3
Scurvy, 147, 148
Sediment, 65, 66
Sedimentary rocks, 65, 66, 67
Servetus, 142
Sexual reproduction, 9, 34
Silicosis, 164
Silvius, 142
Sinanthropus, 127, 128, 129; *pekingensis*, 70, 127
Sivapithecus, 108
Skeletal system, 19
Somatoplasm, 83
Species, 11
Sperm, 34, 35, 37, 43, 44, 46, 83, 160
Spermatozoa, 34
Spirogyra, 26, 29, 32, 36, 42
Spongy, 32
Stalactites, 8
Stalagmites, 8
Stamens, 35
Starches, 146
Stearic acid, 147
Stimuli, 7, 8, 24
Story of Evolution, 4
Stone age, 134
Strata, 67
Stratified rocks, 66
Study of genetics, 49
Stimulus, 7, 8
Sub-phylum, 133
Sushruta, 137
System, endocrine, 19; excretory, 19; nervous, 156, 157; reproductive, 19

Tadpoles, 76
Taxonomists, 74
Telepathy, 98
Teeth, transformation of, 115
Thales, 136, 137
Theory, of evolution, 73, 80; of four humours, 136; of numbers, 136; of organic evolutions, 57, 76, of *Triclosha*, 137
Thinking animal, 160
Thyroxin, 149
Toxins, 164
Transformation of teeth, 115
Triclosha, theory of, 137
Trilobites, 68

Ulothrix, 26
Unicellular, 68
Uranium, 67
Urea, 91

Vaccination, 5
Vacuoles, 29
Vegetable kingdom, 133
Vegetative organs, 23
Ventricle, 138, 142
Vertebral column, 14
Vertebrata, 133
Vertebrates, 14, 19, 75, 76
Vesalius, 142, 143
Vessels, lymph, 165
Vestigial organs, 75, 76, 80
Vitamins, 5, 146, 147, 148, 149, 163, 164

Waste products, removal of, 154
Water, 146, 149

INDEX

Weismann, 83, 84, 87
Wohler, 91
Worms, 36, 57, 64, 68, 90

X-rays, 85, 86

Xylem, 23

Zulus, 40
Zygote, 34, 35, 37, 38, 39, 46, 47, 51, 161

The Story of Life

This book, dealing with the fascinating story of life, is a condensation of the accumulated information on the subject, spread over the pages of scores of books. It has been specially prepared with a view to presenting the fundamentals of the riddle of life in a simple, interesting and easily-understood manner, as it was felt that such knowledge is absolutely essential to all educated persons.

In its comprehensive sweep the book traverses a good deal of ground and essays to deal with such matters as: What is life; Plants and animals in relation to man and their variety and dispension; Structure of cells and characteristics of living matter; The process of reproduction and mechanism of heredity.

Chapters dealing with the evolution of man including the missing links make gripping reading.

The book, which contains thirty-six pages of illustrations at the end of the text, is divided into four parts: The Science of Life; The Evolution of Living Beings; The Evolution of Man; and Working of the Human Body.

Rs. 12.00